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NERC 74 ANNUAL REPORT

National Environmental Research Center
Cincinnati, Ohio

March 1975

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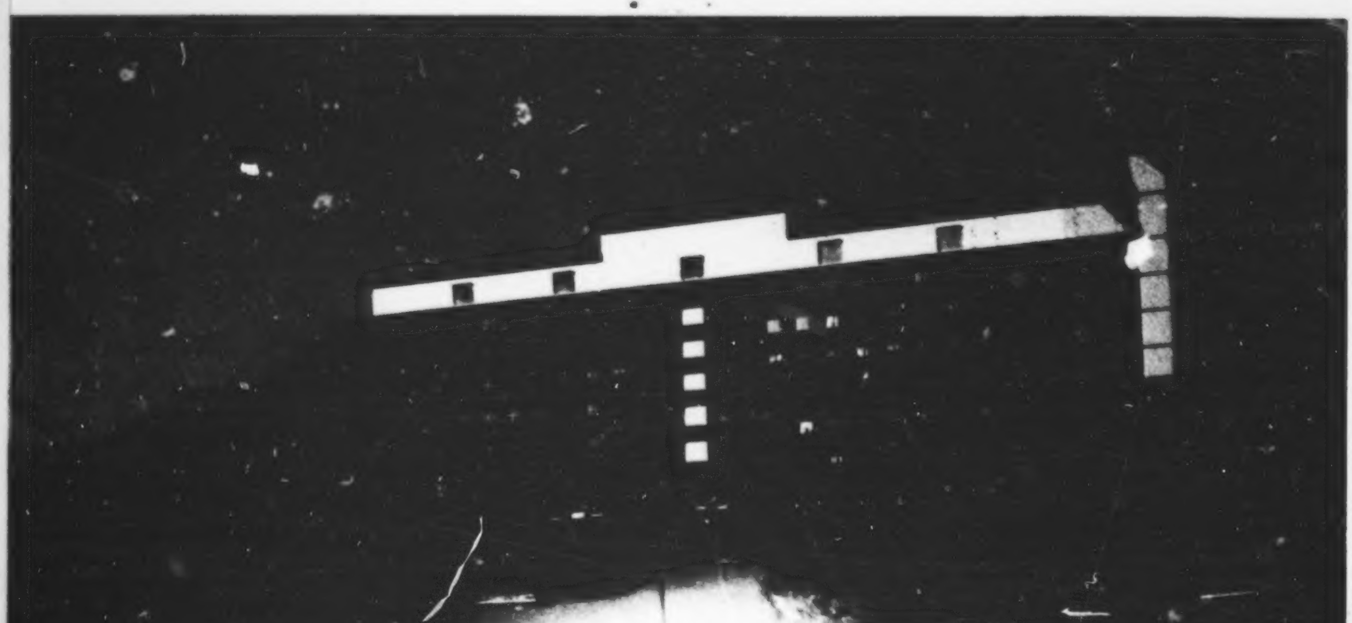

20 YEARS LATER
1954 - 1974

As early as 1913, Cincinnati was a nationally known center in the areas of public water supply and water pollution control. Over the years, radiation, air pollution, solid waste research, training and other technical services became equally important in the environmental work in the government laboratories here. In 1954, the Robert A. Taft Sanitary Engineering Center was dedicated and research into many of these areas was expanded. Over the years, the Center became one of the world's leading research facilities in the anti-pollution field.

1974 marks the 20th anniversary of the building, now designated as the Robert A. Taft Laboratory. Research programs in advanced waste treatment and water supply are conducted at this facility and the administrative offices of the National Environmental Research Center in Cincinnati are presently located here.

In 1975, the National Environmental Research Center's new environmental science complex is scheduled for completion on land adjacent to the University of Cincinnati campus.

We salute the scientists and researchers who have dedicated their efforts in Cincinnati from its beginning as the Stream Pollution Investigation Center to its present status as a major research center of the U.S. Environmental Protection Agency.

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16. ABSTRACT

Research activities of each of the NERC-Cincinnati laboratories are summarized, and a number of contributions made by our staff members to international activities of the EPA are highlighted. Certain projects from the research activities have been chosen for special mention in the text. As this report ~~clearly~~ indicates, FY 1974 has witnessed a significant step forward in the Cincinnati mission to develop pollution control technology in the areas of municipal and industrial waste treatment, municipal water supplies and systems, solid and hazardous waste disposal, pollution identification methodology and monitoring, and toxicological health effects.

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annual report

u.s. environmental protection agency
national environmental research center
office of research and development
cincinnati, ohio 45268

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This report has been reviewed by the National Environmental Research Center — Cincinnati and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

The success of this 1974 Annual Report was made possible through the efforts and the assistance of many people. The Technical Information Staff was fortunate in obtaining the fine cooperation of the laboratory directors and their liaison staff members, and wishes to recognize the anonymous contributors who wrote the feature articles.

Without the special assistance of people such as Mrs. M. Curry, Mrs. E. Cole, Mrs. T. Bayless, Mr. G. M. Gigliotti, Mr. D. W. Dietrich, and Mr. M. E. Folkers, it would have been impossible to undertake this publication.

The full cooperation of the Technical Information Staff in undertaking the editing and publication of this report is gratefully acknowledged.

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foreword

This 1974 Annual Report demonstrates the dynamic nature of environmental research and the strong influence and impact of both national and worldwide economic and political events upon our National Environmental Research Center — Cincinnati research programs.

The energy crisis and economic inflation were forces that motivated new and redoubled efforts to protect and improve our environment at the lowest possible cost in energy resources and dollars. We initiated programs to ensure that inevitable and required energy resource expansion would not be accompanied by environmental deterioration. At the same time, we continued our work to improve and develop existing and emerging municipal and industrial waste treatment pollution control technology, protect and enhance our Nation's municipal water supplies and systems, develop and refine solid and hazardous waste disposal methods, and promote the recovery of valuable discarded resources. We also expanded our efforts in the development of pollution identification methodology and monitoring and the improved generation of toxicological health-effects information.

NERC–Cincinnati enters 1975 anticipating its move into the new facility near the University of Cincinnati. We expect the relocation to be an important milestone in the Center's history. All Cincinnati laboratories will be consolidated in the new research center, and we expect the result to be an increased productivity and complemental spirit among the laboratories and the staff.

It is gratifying to realize that the Center's scientific and supporting staff members are dedicated people respected among their peers. As we continue to strive for excellence, we will uncover those areas where our knowledge can best serve the technical and public communities.

Andrew W. Breidenbach

Andrew W. Breidenbach, Ph.D., Director
National Environmental Research Center
Cincinnati, Ohio

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office of the director

IMMEDIATE OFFICE OF THE DIRECTOR

For the greatest part of the past year, the Immediate Office of the Director was involved in administering the widespread activities of the National Environmental Research Center (NERC) in Cincinnati. In addition to these necessary day-to-day functions, certain specific accomplishments are worthy of note.

Employee Development Plan

In February 1974, the Center implemented a comprehensive employee development plan — the product of a task force appointed in 1973 to evaluate existing employee development and training procedures and to develop a new comprehensive plan. The plan had been reviewed and approved by the U.S. Environmental Protection Agency (EPA) and is now fully implemented. It has won praise from the U.S. Civil Service Commission, and parts of it have been adapted for use on an Agency-wide basis.

NERC/Battelle–Columbus Conference

On May 1, 2, and 3, 1974, NERC–Cincinnati and the Columbus Laboratories of Battelle Memorial Institute sponsored a conference on Pollution Control Technology Assessment. The conference, divided into five sessions, focused on the impacts, direct and indirect, on water quality that have resulted from various actions taken by government and industry in response to environmental control regulations.

Task Force to Define an Office of Research and Development Planning Process

In July 1974, the EPA Deputy Administrator appointed the NERC–Cincinnati Director to chair a task force to define an Office of Research and Development Planning Process. The charge to the task force was divided into two phases: Phase I was to develop a streamlined program planning process for the Energy-Add-On Program by August 15, 1974; Phase II was to develop a simple, effective program planning process for the Agency's overall research and development program by September 30, 1974, for use in the Fiscal Year 1976 planning cycle. This group has completed its work and Phase I has been implemented by the Agency. Phase II is presently being evaluated by the major parties concerned.

Achievement of Operational Status of Electron Microscope Facility

The Director of NERC authorized the establishment of an analytical electron microscope facility in April 1973, and in September 1974, the facility was completed and fully operational. Major features of the system are a JEOL Model JEM 100B transmission electron microscope in combination with a high-resolution scanning device, which gives Center researchers the capability of specimen examination by scanning, scanning transmission, and conventional transmission modes with attainable resolution of 70, 30, and 4.5 angstroms, respectively. With the ORTEC energy dispersive X-ray spectrometer, the system has the capability for performing chemical identifications. The overall system is important because it allows both morphological observation and direct determination of the elemental composition of a specimen.

The operation of the electron microscope facility is unique in that each laboratory using the facility provides its own electron microscope expertise, and the facility is administered under the Director's office, with technical supervision by a committee of principal scientists representing major program users.

Current and programmed research applications include:

- evaluation of distribution, size, kind, and mineral composition of asbestos fibers found in drinking water; this is important because asbestos fibers escaping various treatment processes may present a potential health hazard to particular populations,
- determination of the degree of viral particle aggregation in suspensions; this is important because aggregation can markedly affect interpretation of disinfection kinetics and virus-cell interaction,
- ultrastructural evaluation of tissue morphology after animal exposure to smoke and dust particulates; this is important because it is essential to determine the effects of emissions from mobile and stationary sources on the health of a population,
- evaluation of size and kind of particulates (waterborne sediments, silts, sludges) involved in viral binding and the effect of environmental factors on this binding; this is important because often more viruses adsorb to solids in the sampled water than are found in the waters themselves, and
- delineation of ultrastructural changes in animal tissues resulting from the toxic effect of organic agents and trace metals in water supplies; this is important because very little is known of the possible effects on human health of largely unidentified chemicals entering water supplies.

UC/EPA Linking Pin Committee

Since the formation of the University of Cincinnati — NERC–Cincinnati Linking Pin Committee in 1971, ties between the two institutions have broadened to include joint sponsorship of symposiums, seminars, and publications, and use of University faculty and students by EPA as staff. EPA has found a wide range of experts and consultants at the University to provide needed assistance in computer systems, management studies, and engineering and scientific research. The Linking Pin Committee is now involved in planning three new joint efforts:

- sharing of library holdings and specialization of specific area holdings with joint access,
- collaborating on television services and a physical TV cable link between the new EPA facility and the University, and
- holding a workshop to induce greater activity between EPA employees and University staff in the area of biological research.

PROGRAM COORDINATION STAFF

The Program Coordination Staff (PCS) has primary responsibility for integrating the NERC's diverse research programs into a unified effort that will produce maximum benefits for the resources expended (Figures 1-4). In 1974, PCS made several major new efforts designed to develop personal contacts among individual researchers in the various NERC laboratories and among the same individuals and groups outside the Center with an interest in the NERC–Cincinnati work.

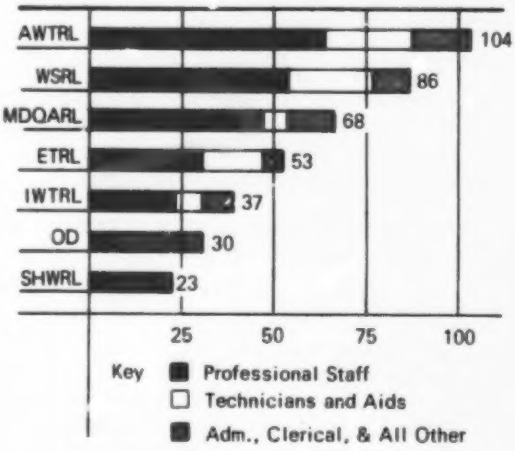


Figure 1. Size and composition of NERC–Cincinnati workforce by laboratory.

Planning and Coordination Meetings

The personal interaction of research scientists and engineers before and during the program planning exercise was recognized as a key factor in properly coordinated research programs. In 1974, such contacts were actively promoted through a series of planning and coordination meetings. Each meeting covered a topic chosen to represent some

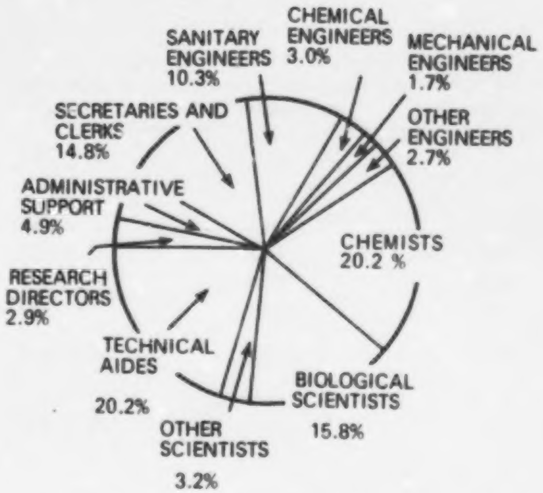
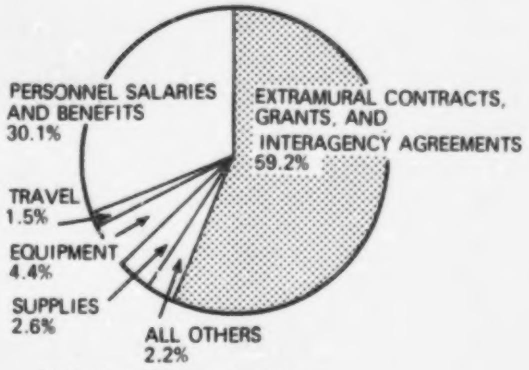


Figure 2. Composition of NERC–Cincinnati workforce by discipline.



*All other expenses include Transporation of things, Equipment Maintenance & Rental Other Contractual Services Etc.

Figure 3. Where the NERC–Cincinnati dollar goes.

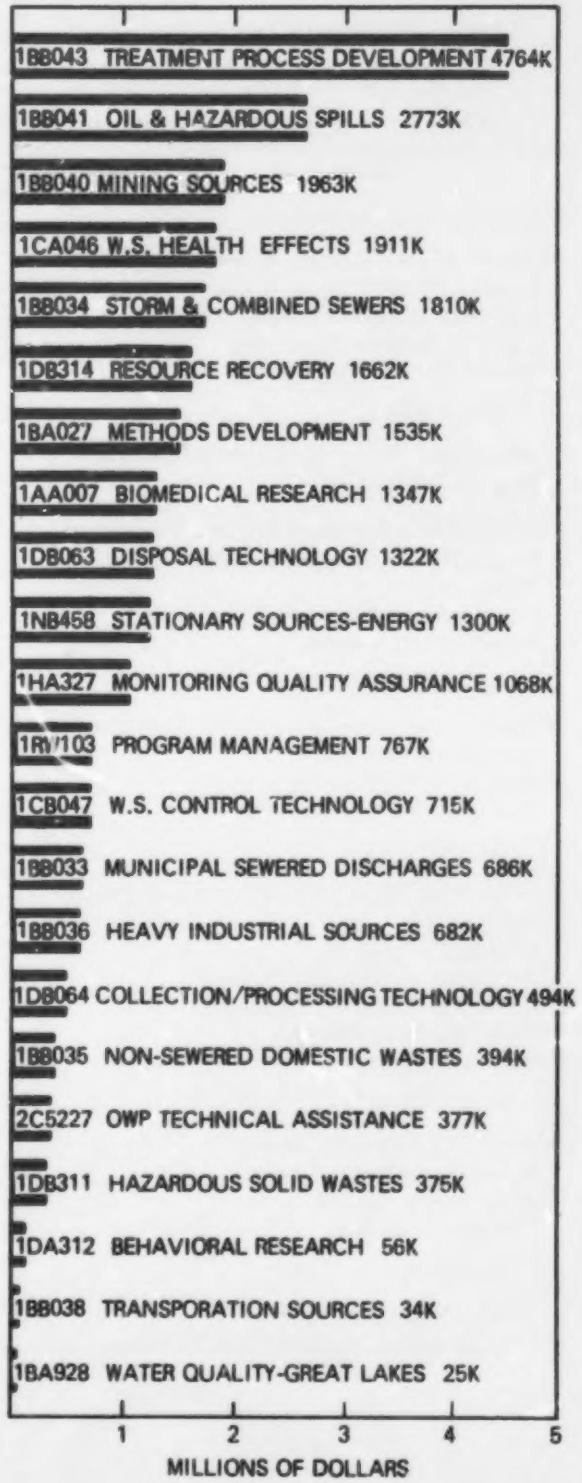


Figure 4. NERC–Cincinnati FY-74 expenditures by program element number.

TABLE 1. NERC–CINCINNATI BUDGET FOR FISCAL YEAR 1974 (IN $1,000)

Laboratory/Office	Intramural	Extramural	Total
Office of the Director, NERC	$ 767	$ —	$ 767
Advanced Waste Treatment Research Laboratory			
Treatment Process Development	2,210	2,554	4,764
Storm and Combined Sewers	166	1,644	1,810
Municipal Sewered Discharges	292	394	686
Nonsewered Domestic Wastes	94	300	394
Total AWTRL	$ 2,762	$ 4,892	$ 7,654
Environmental Toxicology Research Laboratory			
Biomedical Research	$ 1,200	$ 145	$ 1,345
Industrial Waste Treatment Research Laboratory			
Oil and Hazardous Material Spills	512	2,261	2,773
Mining Sources	436	1,527	1,963
Heavy Industrial Sources	187	475	662
Transportation Sources	22	12	34
Total IWTRL	$ 1,157	$ 4,275	$ 5,432
Methods Development and Quality Assurance Research Laboratory			
Methods Development	1,170	365	1,535
Monitoring Quality Assurance	571	497	1,068
Water Quality — Great Lakes	—	25	25
Total MDQARL	$ 1,741	$ 887	$ 2,628
Solid and Hazardous Waste Research Laboratory			
Resource Recovery	—	1,662	1,662
Disposal Technology	307	1,015	1,322
Air Stationary Sources — Energy	—	1,300	1,300
Collection/Processing Technology	87	407	494
Hazardous Solid Wastes	85	290	375
Behavioral Research	56	—	56
Total SHWRL	$ 535	$ 4,674	$ 5,209
Water Supply Research Laboratory			
Water Supply Health Effects	1,525	386	1,911
Water Supply Control Technology	564	151	715
Technical Assistance	377	—	377
Total WSRL	$ 2,466	$ 537	$ 3,003
Total NERC–CINCINNATI	$10,628	$15,410	$26,038

TABLE 2. NERC–CINCINNATI BUDGET FOR FISCAL YEAR 1975 (IN $1,000) (AS OF 8-31-74)

Laboratory/Office	Intramural	Extramural	Total
Office of the Director, NERC	$ 839	$ —	$ 839
Advanced Waste Treatment Research Laboratory			
Treatment Process Development	2,380	2,628	5,008
Storm and Combined Sewers	180	957	1,137
Municipal Sewered Discharges	337	463	800
Nonsewered Domestic Wastes	34	255	289
Total AWTRL	$ 2,931	$ 4,303	$ 7,234
Environmental Toxicology Research Laboratory			
Fuel and Fuel Additives Registration	200	—	200
Biomedical Research	1,615	397	2,012
Total ETRL	$ 1,815	$ 397	$ 2,212
Industrial Waste Treatment Research Laboratory			
Oil and Hazardous Material Spills	496	1,024	1,520
Mining Sources	465	638	1,103
Heavy Industrial Sources	228	588	816
Total IWTRL	$ 1,189	$ 2,250	$ 3,439
Methods Development and Quality Assurance Research Laboratory			
Methods Development	1,369	377	1,746
Monitoring Quality Assurance	735	307	1,042
Total MDQARL	$ 2,104	$ 684	$ 2,788
Solid and Hazardous Waste Research Laboratory			
Disposal Technology	366	1,083	1,449
Hazardous Solid Wastes	150	1,097	1,247
Resource Recovery	55	824	879
Particulate Control	15	657	672
SO_x Control	30	499	529
Behavioral Research	75	—	75
Collection/Processing Technology	10	—	10
Total SHWRL	$ 701	$ 4,160	$ 4,861
Water Supply Research Laboratory			
Water Supply Health Effects	1,639	1,805	3,444
Water Supply Control Technology	718	598	1,316
Technical Assistance	403	—	403
Water Quality Health Effects	85	52	137
Total WSRL	$ 2,845	$ 2,455	$ 5,300
Total NERC–CINCINNATI	$12,424	$14,249	$26,673

relatively self-contained portion of the NERC program that also facilitated interlaboratory contacts.

To provide appropriate background material for the meeting participants, existing programs were analyzed and their component tasks were grouped into topical areas that defined the scope of each meeting. PCS with laboratory cooperation prepared these background analyses, which were collectively termed the Operational Plan. The Operational Plan was thus a listing of all NERC–Cincinnati tasks that would be active any time during Fiscal Years 1974-1976. The tasks contained in each topical area were further analyzed and arranged in workable subgroups by PCS to facilitate discussion.

In all, 17 such meetings were held over a 2-week period in January and February. After an initial sketch by cognizant laboratory personnel, each task was discussed. Where a program overlap or a gap was discerned, the issue was assigned to one or more individuals for explanation or resolution. Both the discussion and the issue resolution phases produced better understanding between the individuals who actually implemented the various programs.

ROAP Network Diagrams

PCS produced and published a book of Research Objective Achievement Plan (ROAP) Network Diagrams using draft diagrams supplied by laboratory personnel. The diagrams graphically displayed the logic by which the tasks and milestones making up the ROAP's were linked together in chronological sequence. Although the diagram was conceived independently of the planning and coordination meetings described, it was used in support of the meetings.

Over 350 copies of the book were distributed within the NERC–Cincinnati Laboratory and to regional offices, other NERC's, Program Area Managers, Office of Research and Development Deputy Assistant Administrators, and all Assistant Administrators in EPA. This effort should increase the understanding of NERC–Cincinnati's programs throughout EPA, and it will be continued with revisions next year.

Regional Visitation Program

A system of visitations to each EPA regional office by the NERC Director and Laboratory Directors was initiated and carried out during the year. The purpose of the program was to familiarize the regional personnel with NERC–Cincinnati programs and to elicit their response on future NERC program planning goals.

PCS prepared briefing documents for each meeting in the form of lists of NERC–Cincinnati's tasks that addressed the research needs submitted by a given regional office. Initially, only selected Laboratory Directors having programs of interest to a particular region attended the sessions at that regional office and discussed programs with various regional personnel. Before long, however, all Laboratory Directors were included in these visits, since unforeseen questions and interests always developed. This program of regional — NERC–Cincinnati liaison strengthens an important but underdeveloped link between one of the producers of EPA research and some of its most important users.

In addition to the these regular visitation programs, PCS coordinated the visits of several regional research representatives to the NERC in Cincinnati to receive briefings by individual laboratory personnel on programs of interest.

Noise

PCS assisted in the development of a ROAP for the Office of Research and Development in the area of noise control technology development. The small effort planned for Fiscal Year 1975 is intended to support EPA's Federal noise control coordination responsibilities.

Energy

PCS was one of several NERC representatives on a task force concerned with preliminary planning of the embryonic energy research program. In cooperation with representatives of other agencies, appropriate research objectives were formulated for interagency research; the Office of Research and Development drew up tentative plans for their own efforts.

CIVIL RIGHTS AND URBAN AFFAIRS STAFF

The Federal Women's Program sponsored two training courses, "Breaking Barriers Thru Speech," specifically designed to meet the needs of women at EPA in Cincinnati. The training was highly successful for the more than 60 attendees, and a similar course will be presented again. In cooperation with the Federal Executive Board, the Federal Women's Program also assisted in presenting an executive seminar on the "Federal Women's Program." The seminar provided guidance for Agency executives in fulfilling their role in the Federal Women's Program.

An Equal Employment Opportunity Seminar for Managers was conducted by EPA–Cincinnati's Civil Rights and Personnel Management Staffs in Fiscal Year 1974. The seminar series, which was conducted at the Columbia Parkway and the Ridge Avenue Buildings, attracted 127 managers and supervisors from EPA in Cincinnati and also some from other agencies, i.e., National Institute for Occupational Safety and Health, U.S. Postal Service, and the U.S. Air Force.

The highlight of the seminar series was a video tape production called "The Situation," which depicted an Equal Employment Opportunity (EEO) complaint situation. The video tape was written, produced, and enacted by members of the EEO Counselor's Committee with the assistance of the Technical Information Staff. The Civil Rights Staff has received numerous requests for use of this video tape from regional offices and NERC's within EPA as well as several offices of the Internal Revenue Service. EPA Headquarters has requested a duplicate tape for their permanent use.

The Civil Rights Staff, in its effort to promulgate the concept of Upward Mobility, compiled a compendium entitled "Upward Mobility is a Step in the Right Direction . . . or . . . Everything You Wanted to Know About Upward Mobility but were Afraid to Ask." The compendium has been distributed to each NERC and regional office, with EPA Headquarters printing additional copies for their retention; copies have been distributed to the International Personnel Management Association and to the U.S. Civil Service Commission, Washington, D.C., for use in their Upward Mobility Workshop Courses.

PUBLIC AFFAIRS STAFF

The Public Affairs Staff issued news releases on subjects ranging from energy policy to environmental plans in research; approximately 5,000 pieces of literature were mailed out, and a large number of telephone and written inquiries were handled.

In May, our second annual Open House attracted over 700 high school and elementary students and teachers.

A number of questions on the new unleaded gasoline regulations were referred to Region V headquarters, especially those seeking an extension on the deadline for reasons of material shortages in nozzles and other necessary hardware.

The meeting of top EPA management personnel at NERC–Cincinnati resulted in a press conference and local print and TV coverage, with a feature story on NERC appearing in the Louisville Courier Journal.

TV appearances for other visiting officials was a continuing activity of the Public Affairs Staff. The EPA Administrator appeared on a TV show covering three midwest cities and was interviewed by the press during his visit in September. The NERC Director appeared on WCPO TV's Noon Report twice and also was interviewed on WWEZ Radio in relation to an energy paper prepared by the Director and his staff.

Film crews from CBS and NBC visited NERC–Cincinnati for special reports on drinking water research. Programs were taped and shown on national television and on a continuing basis in the lobby of the Taft Laboratory.

The Public Affairs Staff also coordinated publicity for the dedication of the OHMSETT site at Edison, New Jersey, in early October and the design and construction of an exhibit for the Louisville, Kentucky, "Coal and the Environment" conference in October.

The Public Affairs Staff continued to report on the progress of the new facility near the University of Cincinnati through EPA Progress Reports.

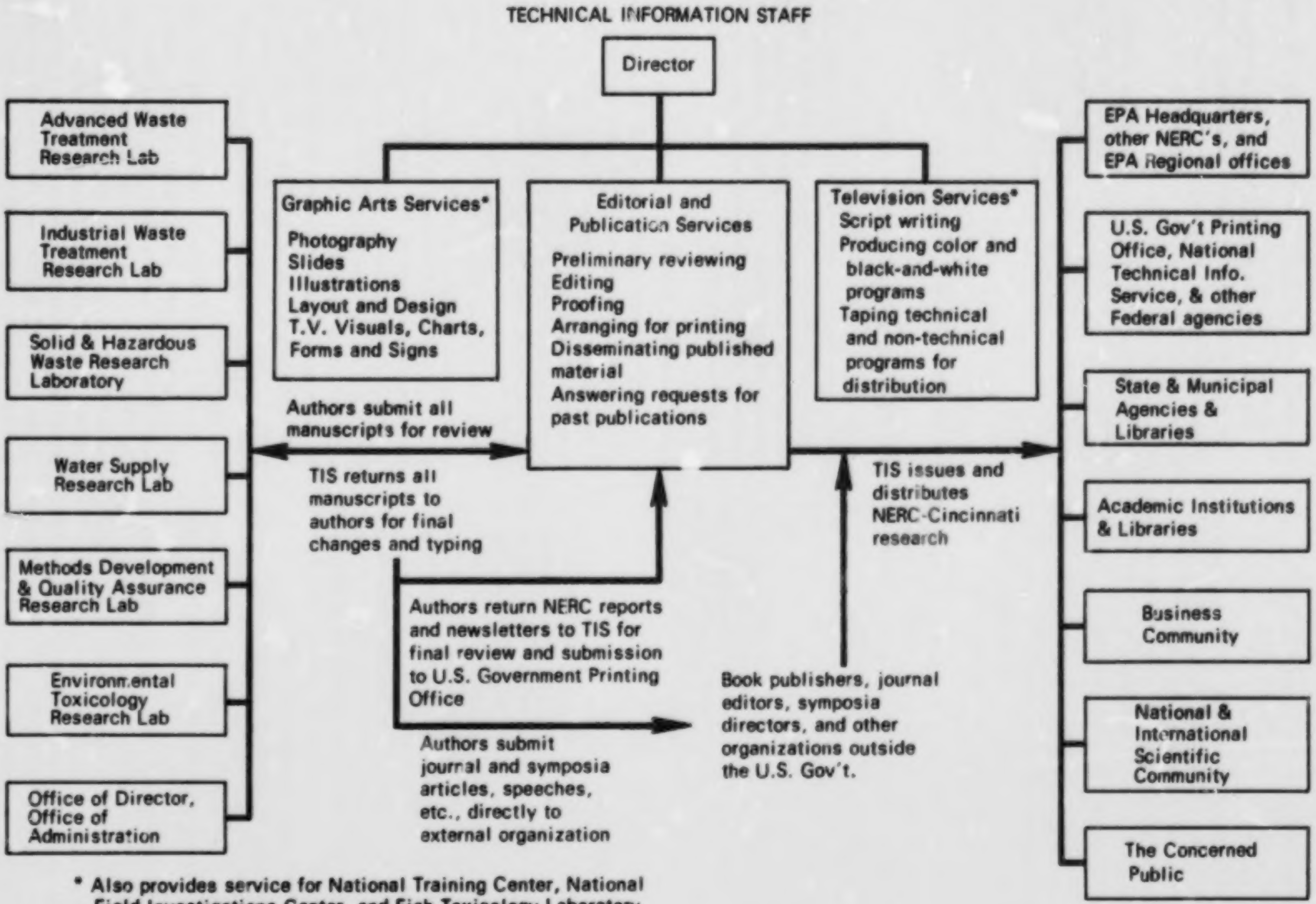
TECHNICAL INFORMATION STAFF

During 1974, the Technical Information Staff (TIS) contributed to the third year of NERC–Cincinnati growth by informing the national and international communities in government, education, and industry of the research programs performed or underway at the various laboratories of our environmental research complex.

Editorial and Publications

Researchers and administrators of NERC–Cincinnati submit all manuscripts intended as technical reports, symposia or journal articles, and conference speeches to the editorial staff for editorial review and clearance (Figure 5). During 1974, the TIS processed and cleared for publication 119 NERC "in-house," contract, and grant reports; edited and cleared 14 newsletters and 150 journal and symposia articles and conference speeches. The TIS continued to encourage and publish brief, informative explanations of key research in progress at NERC–Cincinnati in the "News of Environmental Research in Cincinnati" newsletter sent to a large technical and nontechnical audience. Topics covered by these newsletters included the timely "Impact of Environmental Control Technologies on the Energy Crisis," "Sludge Incineration and Fuel Conservation," "Catalytic Converters Used in Health Studies," and many others.

In 1974, the TIS began reviewing NERC–Cincinnati contract and grant reports before preparation of the final camera copy that TIS submits to the EPA printer and/or to the National Technical Information Service (U.S. Department of Commerce) for publication. During this review, the report is examined for completeness and adherence to the standard format specified for all research and development studies supported by the Office of


TECHNICAL INFORMATION STAFF
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Methods Development & Quality Assurance Research Lab
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TIS returns all manuscripts to authors for final changes and typing
Authors return NERC reports and newsletters to TIS for final review and submission to U.S. Government Printing Office
Authors submit journal and symposia articles, speeches, etc., directly to external organization
Book publishers, journal editors, symposia directors, and other organizations outside the U.S. Gov't.
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U.S. Gov't Printing Office, National Technical Info. Service, & other Federal agencies
State & Municipal Agencies & Libraries
Academic Institutions & Libraries
Business Community
National & International Scientific Community
The Concerned Public

* Also provides service for National Training Center, National Field Investigations Center, and Fish Toxicology Laboratory

Figure 5. The role of the Technical Information Staff (TIS) in communicating NERC–Cincinnati research.

Research and Development of the EPA. The quality of final reports being submitted has significantly improved and has, in many instances, decreased publication costs.

In addition to these activities, TIS distributes NERC–Cincinnati research reports, published proceedings of NERC-sponsored symposia, reprints of journal articles, and "News of Environmental Research in Cincinnati," to over 5,000 individuals and organizations who comprise our updated mailing list and to the thousands of parties who requested NERC–Cincinnati publications in 1974. These requests and mailing lists for mass mailing are handled from the Publications Distribution Unit of the TIS, which sent publications throughout the United States and to foreign countries from Madagascar to Malaya. TIS has also been given the responsibility for the publication and distribution of NERC–Cincinnati's Quarterly Report.

Graphic Arts Unit

The Graphic Arts Unit has become an integral part of NERC–Cincinnati research efforts, assisting all programs with technical, scientific, and specialized visual information material.

By working with program personnel, writer-editors, and printers, the Graphic Arts Unit personnel has been able to ensure good service and quality work, with an overall 1974 workload increase of 21% from that of 1973. Most of the increase has been in requests for photography and for slide presentations.

Major in-house graphic services include:

- photography (black and white and color taken at our shop or at location),
- slides (color and black and white, which are developed in-house for better quality control),
- illustrations (technical, nontechnical—in all media),
- layout and design (promotional material, technical reports, brochures, pamphlets, cover designs, and certificates), and
- TV visuals, charts, forms, and signs.

Television Production Unit

Television productions are a valuable means to introduce new employees and trainees to NERC–Cincinnati, to acquaint foreign and domestic visitors with some of the research programs underway here, and to educate outside scientists, businessmen, and educators on the importance and application of the knowledge and technology developed at NERC–Cincinnati to their particular research needs.

To produce a stimulating and informative technical program calls for:

- script writing, with the close cooperation of writer and scientist to effectively and concisely convey often complex laboratory techniques, instruments, and results,
- program production and film editing, with technical expertise in recording the visual and audio dimensions of the film and, with imagination, in creating interesting ways to present the scientific material,
- program taping, with care in exact production of the program for later distribution and use.

Highlight productions of 1974 include:

- an orientation program in which the NERC–Cincinnati Director and the various Laboratory Directors explain (in English, Spanish, Polish, and Japanese) the Center's environmental mission, the NERC–Cincinnati Research Laboratories, and some of the ongoing research programs,
- a video-taped explanation of CAM–1, an instrument developed under EPA contract to automatically monitor water supplies for toxic levels of pesticides; the tape was sent to Dr. D. H. Newsome of England's Water Resources Board to aid a special symposium there on the monitoring and maintaining of water quality standards,
- a program describing the NERC–Cincinnati library facilities, particularly the new computer information retrieval system,
- a role-playing skit ("The Situation," described by the Office of Civil Rights and Urban Affairs) to dramatize for EPA managers the process of handling employee grievances, and
- a number of training films for NERC laboratories and the National Training Center to illustrate laboratory techniques and equipment operation.

OFFICE OF ADMINISTRATION

The Office of Administration (OA) provides day-to-day support services to EPA organizations in Cincinnati and also to various agency installations not located in Cincinnati. These services include contracting, facilities management, library, financial management, personnel management, and computer services and systems.

In May 1974, the NERC–Cincinnati OA hosted the Second National Planning and Management Conference attended by approximately 240 employees representing the 10 regional offices, 4 NERC's, other field installations, and Headquarters. In addition to the general session, specialty meetings were held by audit, contracts management, financial management, personnel management, and planning and evaluation groups. The general session provided an opportunity for senior management officials to discuss planning and management activities and problems. The specialty meetings were attended by working-level staff to deal with specific subject area problems. A large number of action items were developed at these meetings.

Contracts Management

The Contracts Management Division provides procurement and contracting support to EPA laboratories in Las Vegas, Nevada; Corvallis, Oregon; and Ann Arbor, Michigan, in addition to EPA Cincinnati. Workload statistics increased substantially from 262 contract actions for $10,000,000 in Fiscal Year 1973 to 473 contract actions for $25,000,000 in Fiscal Year 1974. Approximately half of these contract actions were executed in support of Cincinnati EPA activities.

Small purchases (under $2500) increased from 6,500 to 7,000 transactions; 3,000 of these were placed utilizing the new and simplified oral order technique. The 3,000 figure is significant in that it surpassed projected usage by 1,000 and reduced both processing and leadtime for selected transactions by as much as 7 to 10 days. Approximately 90% of small purchase transactions were executed in support of Cincinnati EPA activities.

In July 1974, a change to the Federal Procurement Regulations increased the authority to negotiate small purchases from $2500 to $10,000. This increase in authority will make it possible to achieve future significant economies; however, because additional changes must yet be made to other statutes and regulations that impose thresholds less than $10,000, the potential for savings will not be determined for several months.

Facilities Management and Services

The progress on the new facility in the past year has been outstanding. The building seemed to virtually "leap out of the ground" (Figures 6-10). The building was topped out in July; therefore, the weather will no longer be a prominent factor in the scheduled completion date — summer of 1975.

Two major design changes have been incorporated to comply with the requirements of the new Occupational Safety and Health Act (OSHA); all laboratory doors now swing outward and all laboratory electrical circuits are provided with ground fault interrupters to minimize the chance of electrical shock. This facility, when completed, will meet all OSHA requirements and will have one of the safest working environments of any laboratory of comparable size.

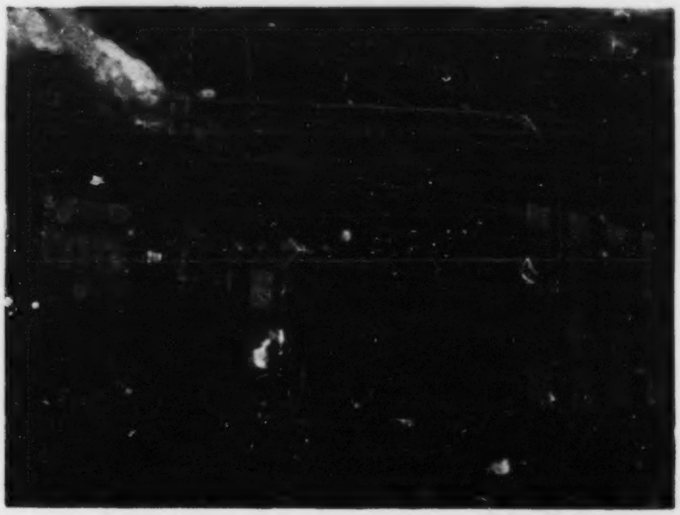
The occupants of the building will include the Office of the Director, the Water Supply Research Laboratory, the Methods Development and Quality Assurance Research Laboratory, the Environmental Toxicology Research Laboratory, the Solid and Hazardous Waste Research Laboratory, the National Field Investigations Center, the National Training Center, the Office of Administration, and the Radiochemistry and Nuclear Engineering Facility. The space assignments have been made, and the construction drawings have been revised to show the room layouts and the laboratory furniture. Detail planning has started on the actual move to the new facility.

The cumulative effect of the completion of many repair and improvement projects at the Robert A. Taft Laboratory was to advance the operation of building equipment to new levels of capability and provide heretofore unavailable levels of safety, improved building functions, and enhanced building appearance; specifically, increased air conditioning capacity; pure water supply; heating, ventilating, and air conditioning controls; site improvements for control of water damage; lighting; acoustical work; room finishes for offices and training rooms; parking improvements and landscaping. This year the Robert A. Taft Laboratory received the Cincinnati Chamber of Commerce award for outstanding landscaping.

In concert with program personnel, especially those scheduled to move to the new facility, the Personal Property and Supply Management Office conducted a drive to reduce inventories of materials and equipment. A total dollar value of $1,456,000 of excess/surplus material was transferred to other Federal agencies and donated to State activities. This had a beneficial effect on the EPA programs by decreasing the cost of the physical move, reducing requirements for warehouse space, and reducing inventory controls. It also saved the receiving organizations' equipment expenditures. Additionally, equipment valued at $400,000 was reassigned within EPA–Cincinnati to further reduce their purchasing expenditures.

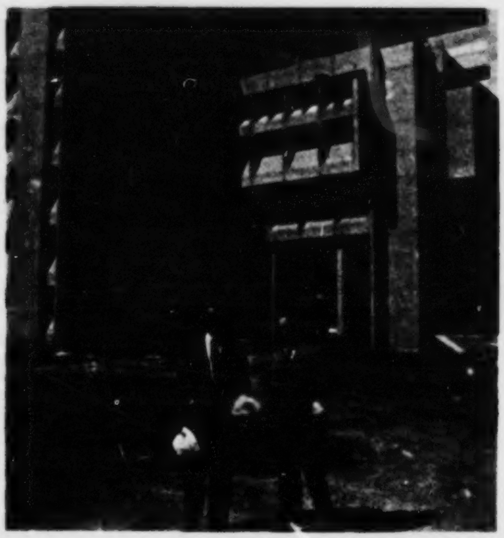
In the printing management area, approximately $20,000 (10% of the annual amount expended for printing) was saved through cost analysis of *each* printing job and closer coordination between the office of origin, the NERC–Cincinnati printing office, U.S. Government Printing Office, and printing contractors.

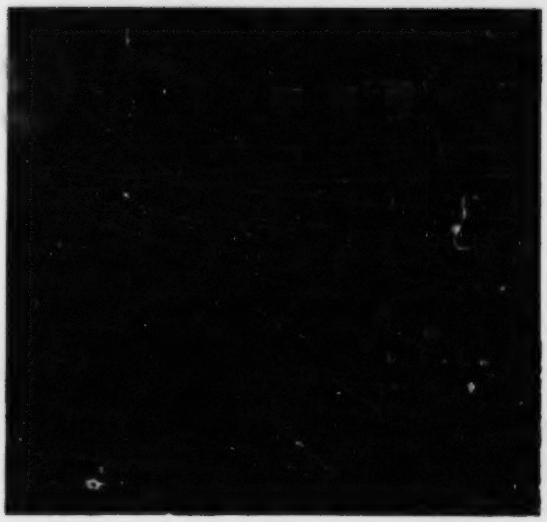
The Insurance Company of North America Survey Team conducted a safety survey of the NERC during September 1973. The report was received in the late spring of 1974. Correction of deficiencies is progressing.

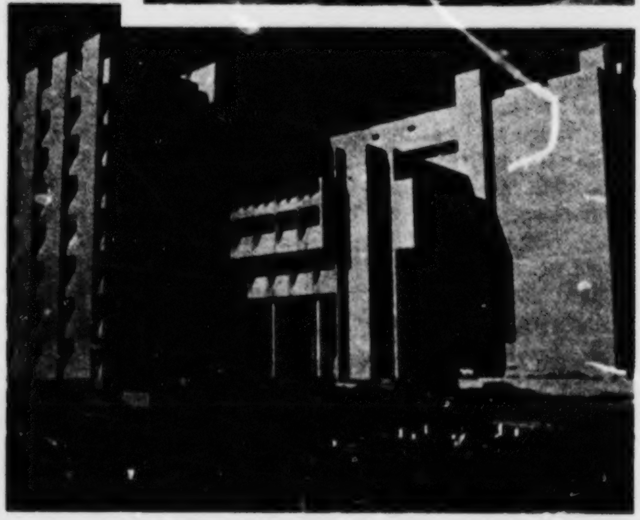


1974 Progress in construction of the new Cincinnati facility can be seen in Figures 6–10.

Top left, March.
Center left, June.
Center right, September.
Bottom left, November.
Bottom right, January 1975.







Library

This year, as a result of automated library operations, the NERC–Cincinnati Library has provided increased and more efficient service to a greater number of clients than in any previous year. A record number of searches, over 5,000, have been made for EPA researchers nationwide. The online literature search system has access to more than 25 computerized data bases, containing over 10 million document citations.

Awareness of broader coverage of world literature on various subjects has brought an increased demand for inter-library loans and document delivery. Through inter-library loans, networks, and contracts with several large university libraries, thousands of documents requested by library users have been obtained.

During 1974, 37 foreign articles have been translated through use of the EPA contract.

Considerable time and effort have been devoted to planning the space layout and equipment needed for the library in the new EPA facility, as well as plans for providing a branch library to accommodate the staff remaining at Taft Laboratory.

Financial Management

Upgrading equipment for recording input of accounting transactions and receipt of financial reports in the accounting operations office has resulted in an annual rental savings of $5,700. In addition, data processing records the input faster and allows direct input to the Headquarters computer. Reports previously mailed from Washington are now transmitted to our local finance office via computer terminals, which saves 7 to 10 days in distributing the various accounting reports to management. The addition of a Data Set device approximately doubled the speed of printing the reports.

Additional responsibilities resulted from Agency integration of record keeping and fund-control processes. This system has been successfully put into operation and has made mechanized records accessible to the research programs and, thereby, made possible more accuracy as well as savings in manhours spent on record keeping.

Changes in the procedure on paper flow for airline tickets has enabled the office to audit invoices more efficiently and reduce the time lag for processing payments to vendors.

Computer Services and Systems

During 1974, the Computer Services and Systems Division has significantly expanded its services through the use of a Systems Design and Programming Support Services Contract with the University of Cincinnati and an Interagency Agreement with the Atomic Energy Commission's Lawrence Livermore Laboratory.

The support services contract with the University of Cincinnati has provided a quick and easy mechanism to assess a wide range of technical experts from the University's faculty and data processing staff who have assisted EPA scientific personnel in a variety of computer-related activities. Approximately 20 tasks that provided support to each of the EPA Cincinnati laboratories were initiated and completed during 1974.

The purpose of the Interagency Agreement with Lawrence Livermore Laboratory is to develop a total computerized laboratory automation system for EPA in Cincinnati and assist other EPA laboratories in automation through the transfer of technology developed in Cincinnati; the result will be a significant cost and time savings.

Working closely with the Office of Research and Development's Office of Monitoring Systems, the Office of Planning and Management's Management Information and Data Systems Division, and regional laboratories, we are promoting the development of standard hardware/software configurations, minicomputer laboratory instrument interfaces, data analysis and sample logging routines, and interconnection with larger general purpose computers.

During 1974, orders were placed for computer related equipment for automation at the NERC–Cincinnati's Methods Development and Quality Assurance Research Laboratory (MDQARL) and Advanced Waste Treatment Research Laboratory (AWTRL). In addition, the Office of Enforcement and General Counsel's National Field Investigations Center (NFIC) in Cincinnati and the EPA Region V Surveillance and Analysis Laboratory also ordered equipment. Additionally, assistance has been provided to Regions I, II, and III.

Personnel Management

In concert with the Civil Rights and Urban Affairs Staff, the Personnel Management Office launched a full-scale campaign to sensitize managers and supervisors to the problems of underutilized minority and female employees. A number of personnel procedures and mechanisms were established within the Affirmative Action Plan to provide management with a powerful tool for effecting change in the EEO area.

Training and Employee Development Programs have been established to ensure maximum utilization of manpower. During this past year, efforts included issuance of policy and procedures for an Employee Development Short-term Training Program. In addition, training courses were conducted on performance appraisals, employee conduct, merit promotion, and grievance procedures. Orientation sessions for new employees were also held at the various facilities.

This year a bargaining agreement was negotiated with the National Federation of Federal Employees, exclusive agent for all nonprofessional General Schedules nonsupervisory employees. This will provide improved labor management relations at the Center.

A number of steps were taken toward effectively utilizing human resources in accomplishing mission objectives. An example is the implementation of a classification and position management committee to ensure that organizational and position structures are designed and reviewed to produce maximum effectiveness within the resources available. Individual positions are classified in a more systematic manner, and the classification impact of relationships among positions is considered.

Numerous awards have been conferred upon outstanding employees during the present year. For the period January 1 through September 30, 47 quality increases were awarded for continued high quality performance above that ordinarily found in the type of position concerned. In addition, 36 special achievement awards were awarded for special acts or services.

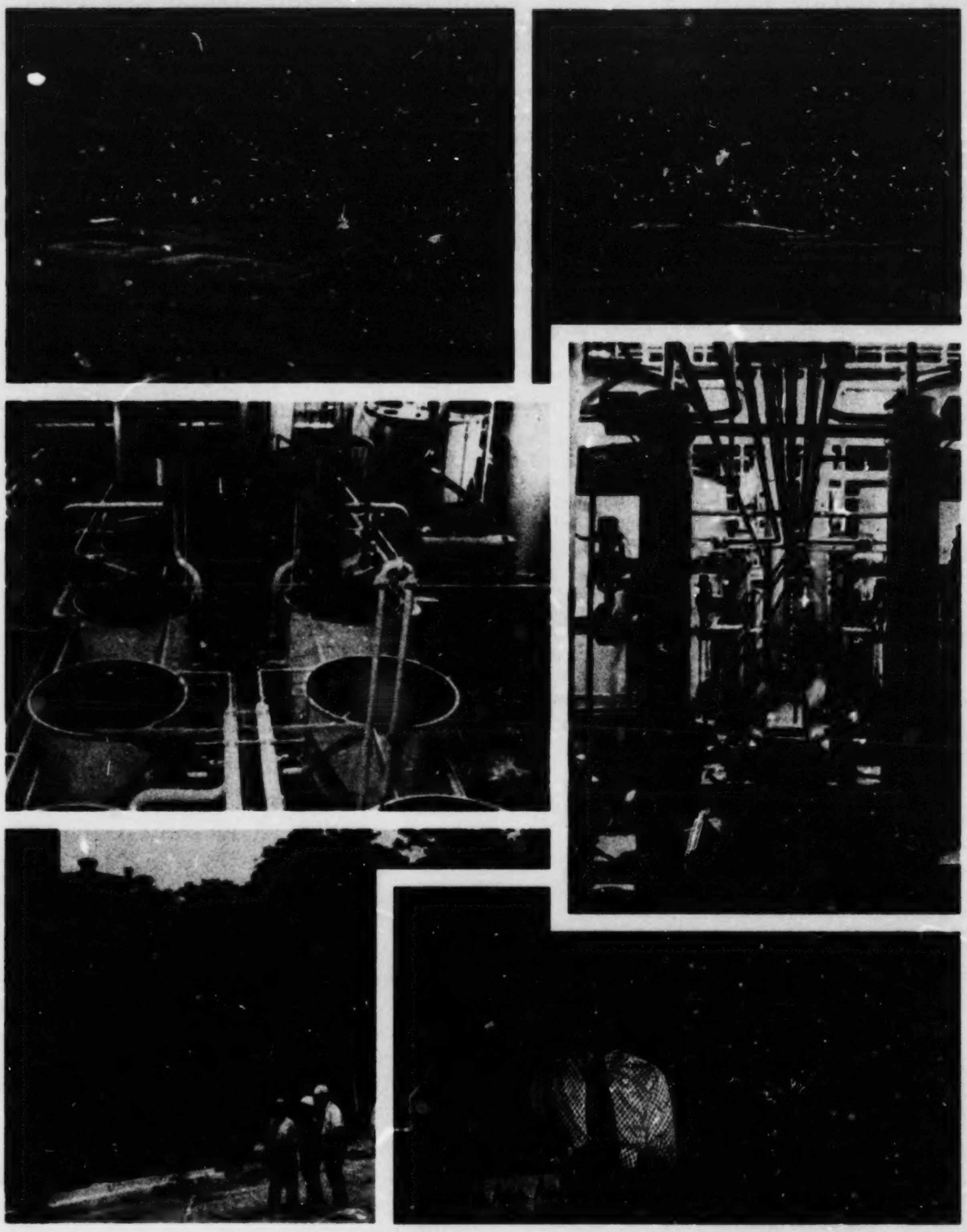
A Bronze Unit citation was granted to the 30-member Contracts Management Staff for meritorious service to the mission of environmental protection by providing procurement service and support necessary for the timely and efficient accomplishment of program objectives. At our January Award Day, length of service awards were given to 108 employees for having obtained a significant milestone in government service during calendar year 1973.

A 1-year mobility assignment under Title IV of the Intergovernmental Personnel Act was effectuated on September 15 when Dr. Carl Charles, Georgia Institute of Technology, was detailed to the Advanced Waste Treatment Research Laboratory. This mobility assignment allows the sharing of scarce expertise in the field of urban storm pollution control.

NERC RELATIONSHIPS

Nonresearch components of the Environmental Protection Agency also have activities in Cincinnati, Ohio: The National Field Investigations Center, a division of the Office of Enforcement and General Counsel; and the National Training Center under the Water Programs Operations Office. The Office of the Director of NERC–Cincinnati furnishes these organizations with administrative and other support services through the Office of Administration. Program direction is provided from the cognizant Assistant Administrators' offices in Headquarters.

NERC–Cincinnati staff maintains a continuous communication and information exchange with these EPA activities as well as with the other three National Environmental Research Centers in Corvallis, Oregon; Las Vegas, Nevada; and Research Triangle Park, North Carolina.



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advanced waste treatment research laboratory

The advanced waste treatment program was initiated in Cincinnati in 1960 in response to the Federal Water Pollution Control Act. Until EPA was established in December 1970, research had been conducted under the auspices of the U.S. Public Health Service and, later, the U.S. Department of the Interior.

The Advanced Waste Treatment Research Laboratory (AWTRL) currently develops new methods and improves existing methods for wastewater treatment and reuse to achieve the goals of Public Law 92-500. Most of the studies are centered on municipal wastewater treatment; however, much of the methodology is also adaptable to treatment systems for industrial and agricultural wastewaters. For most of 1974, the Storm and Combined Sewer activities have been included under AWTRL.

INTRODUCTION

Advanced wastewater treatment, once thought of as being concerned only with purifying water for reuse, actually means any process, technique, or system that will improve wastewater pollution control technology. In the broad sense, any modification that will reduce the cost of treatment to meet water quality objectives or effluent standards is an improvement. Through AWTRL research in the past year, three different improvements have been developed that have in common the fact that they offer the potential of reducing treatment costs while meeting appropriate standards. It is significant that two of these processes also substantially reduce the energy requirements for treatment. In the third case, savings in land area required for treatment is the most significant factor.

The three processes referred to are illustrated in Figures 11-15, 17. The first is lagoon upgrading to make the quality of the effluent from this low cost treatment method equivalent to that of secondary treatment. The second is simultaneous nitrification and denitrification, which has potential for plants that should reduce nitrogen compounds in the

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effluent to protect receiving waters. The third process involves substituting chemical treatment followed by carbon adsorption in place of conventional biological treatment to achieve comparable effluent quality. Pilot studies at Pomona, California, have produced design data for a plant to serve nearly 100,000 inhabitants at Rocky River, near Cleveland, Ohio.

The completion of research and the successful development at a pilot plant or demonstration at a full-scale plant solves few problems if the new technology does not reach the engineers and city officials who can put the results to work. To implement its R&D effort, the AWTRL cooperates closely with the Office of Technology Transfer in their design seminar program (Figure 16). Key scientists and engineers present lectures covering research and case histories of successful applications of new technology to audiences composed of civil engineers and others responsible for the design and implementation of waste treatment plants.

SPECIAL TOPICS

Lagoon Upgrading

Approximately 90% of the wastewater lagoons in the United States are located in small communities with fewer than 10,000 people. For these small communities, lagoon treatment has proved to be a relatively stable system able to handle fairly wide diurnal or daily fluctuations in wastewater flow and organic loading. The fluctuations have little effect on effluent quality because the long detention times provide great equalization of flow and load. Lagoons generally cost less than other biological processes to install, and they do not require around-the-clock surveillance.

Although well-designed and operated lagoons meet the Secondary Treatment Standards most of the time, a survey showed that excessive suspended solids (primarily algae) seriously affect performance. Lagoon capabilities and deficiencies needed reappraisal to determine the advisability of new lagoon construction and to decide whether economical methods could be found for successfully upgrading the more than 4,000 existing lagoons or whether they should be replaced with other means of secondary treatment.

Finding a simple, low-cost method for removing algae and suspended solids from lagoons effluents — one that could be used by small communities where round-the-clock maintenance was not provided — was deemed the most important task. Projects were funded involving filtration through soil by spray irrigation with or without crops growing on the land (Utah State University) and through an intermittent slow-sand filter at Logan (Utah State University). These methods take advantage of the improved filterability of algae when liquid passes slowly through the filter medium and also the improved biological activity within the pore spaces of the soil and upper surface of the slow-sand filter to aid in destroying algal material and preventing rapid filter clogging. When the upper few inches of the slow-sand filter do become clogged, they are physically removed and another filtration cycle is started. For the intermittent slow-sand filter and soil irrigation methods, the effluent is generally added once a day; this is followed by a period of drying. At least a pair of intermittent slow-sand filters would be needed at any lagoon site to allow one to be used while the surface of the other filter was being scraped.

In the foreground of Figure 11 is the set of six experimental slow-sand filters at Logan, Utah, where the effects of various hydraulic loadings are being studied. The treatment lagoons for the city occupy the middle of the picture. Preliminary results indicate good removal with the intermittent slow-sand filter. The rates ranged from 0.2 to 0.8 m/day (0.2 to 0.8 million gal/acre), and the average effluent suspended solids ranged from 4 to 8 mg/l when the average influent suspended solids was 26 mg/l. Preliminary results of the soil percolation studies were not yet available at the time of this writing; however, application rates of 5 to 35 cm/wk (2 to 14 in./wk) appear to be feasible.

When all data are in, it should be possible to show that the total costs for upgrading and maintaining upgraded lagoon systems are still considerably lower than the cost of replacing the lagoons and maintaining secondary treatment plants. The preliminary results of these first-generation lagoon upgrading projects indicate that lagoon wastewater treatment systems with modifications will continue to be a cost-effective option for wastewater treatment in small rural communities.

Single-Tank Nitrogen Removal

When municipal waste treatment plants must remove nitrogenous wastes, the expense can be considerable. Work at the EPA–DC pilot plant in Washington, D.C., has shown that greater than 80% nitrogen removal can be obtained in a single-tank biological system. This system is in contrast to the multi-tank nitrogen control process, which utilizes several tanks in series and requires the addition of methanol to reduce nitrates to nitrogen gas. Although the multi-tank approach has proven effective where high efficiencies are needed, the single-tank system could apply where effluent requirements are less stringent.

Biological removal of fixed nitrogen requires conversion of ammonia to nitrate by slow-growing nitrifying bacteria. In a multi-tank system, nitrification takes place after excess sludge-forming organic matter is removed. The second stage involves reduction of nitrate to nitrogen gas by heterotrophic bacteria, which use the oxygen in the nitrate ion to oxidize organic matter. The denitrification stage has conventionally been fed with methanol, a pure, easily handled organic chemical that has alternative uses as a fuel.

A partially baffled, single-tank system was operated at the EPA–DC pilot plant at a very low food-to-microorganisms ratio. A 30-min cycle of air to furnish 2 to 3 mg of dissolved oxygen/l was alternately directed to each side of the baffle. When the air was off, the dissolved oxygen on that side of the tank dropped to near zero. This procedure leads to development of a culture containing organic carbon oxidizers, ammonia oxidizers, and nitrate reducing bacteria. During the air-on cycle, organic carbon and ammonia are oxidized; during the air-off cycle, nitrate oxygen serves to furnish the oxygen for organic carbon oxidation, with the coincident reduction of the nitrate to harmless nitrogen gas. In the two-pass reactor in warm weather, the required detention time was 9 hr for a residual total nitrogen content of 4 mg/l in the effluent. In wintertime, the required tank detention time was 12 hr for a residual of 6 mg/l.

A single-stage system offers several potential advantages over a multi-tank system in temperate climates. It requires no external source of organic carbon, such as methyl alcohol, and therefore, chemical costs will be reduced by as much as $250/day in a plant serving a population of one million people. Total air requirements will be reduced since the oxygen in the nitrate radical is used to oxidize part of the influent organic carbon. Separate tanks and extra clarifiers are not required so the single-tank system should require less capital expense.

Granular Activated Carbon for Wastewater Treatment

Physical-chemical treatment produces a high quality effluent and offers advantages when compared with conventional biological treatment methods, i.e., smaller land area, lower initial capital costs, insensitivity to toxic materials such as metals, and the capability of removing nondegradable toxic organic compounds.

At one time, use of chemical clarification and adsorption on activated carbon was considered only for a "polishing" application to biologically treated effluents. It is now clear that the application of carbon to raw wastewater after chemical clarification is both technically and economically sound. At a pilot plant in Pomona, California, substantial advances have been made in the use of activated carbon for treating chemically clarified raw wastewater to produce "secondary" or better effluent quality. Raw wastewater is chemically clarified with alum and polymer followed by granular activated carbon in a pressurized column (Figure 17).

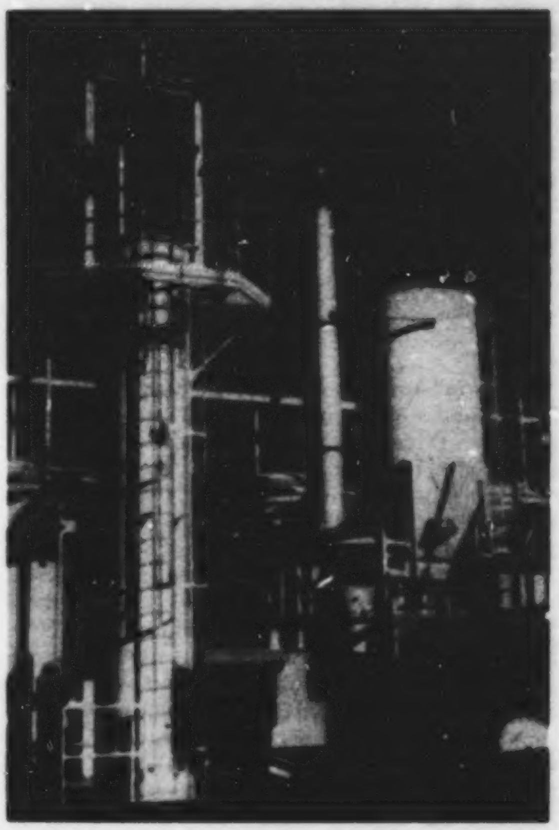


Figure 17. Carbon columns and carbon regeneration furnace at Pomona, California.

Experience to date indicates that the clarification process alone will remove 90% to 95% of the suspended solids, 60% to 80% of the total COD, and more than 90% of the total phosphate. The clarification process will also remove 90% to 95% of most metals. The process is highly reliable and is subject to few known interferences.

Dissolved organic material remaining in the chemically clarified raw wastewater is removed by granular activated carbon. As originally conceived, the role of activated carbon was simply to remove organics by adsorption. It is now clear that the process is far more complex than envisioned and that carbon contactors are supports for biological growth. Carbon can remove metals, perhaps as organic complexes, and a wide array of potentially hazardous organic compounds can also be removed, including pesticides, carcinogens, taste and odor producing substances, and nondegradable synthetic organics in general. Certain soluble, low-molecular-weight organic compounds, however, are not adsorbed by activated carbon. Typical results at Pomona are compared with biological treatment:

Parameters	*Physical-Chemical*	*Activated sludge*
Suspended solids, mg/l	4.2	20.3
Turbidity, JTU	4.3	15.7
Total COD, mg/l	11.2	41.6
BOD_5, mg/l	5.5	7.9
Total phosphate-P, mg/l	0.6	—
Color, units	7	39

Thirty full-scale physical-chemical treatment plants are in various stages of planning, design, and construction. During the past year, some notable advances have been made, particularly in the carbon process. A major problem with carbon contactors has been the production of sulfides that resulted from anaerobic conditions produced by biological action in the column. At Pomona, additions of sodium nitrate completely suppressed sulfide formation. Adding 5.5 mg nitrate-nitrogen/l not only prevented the formation of sulfide but also permitted a very high organic "loading" on the carbon. Instead of the more typical loading of about 0.5 lb of COD per lb of carbon, the organic loading at Pomona was 3.54 lb. Furthermore, at the end of 15 mo of continuous operation the carbon was still removing 75% of the applied COD. Obviously biological action on the column was destroying organic matter utilizing oxygen from the nitrate ion in the process.

Even though effluent quality never deteriorated to an unacceptable level at Pomona, the decision was made to regenerate the carbon since, up to that time, regeneration of carbon used to treat chemically clarified raw wastewater had not been demonstrated. Subsequently, three adsorption-regeneration cycles were conducted. In all respects, the regenerations were as successful as the previous experience at Pomona where some 30 regeneration cycles had been conducted on tertiary mode carbon. The three carbon regenerations also provided the opportunity to observe the effectiveness of the air pollution controls.

TREATMENT PROCESS DEVELOPMENT BRANCH

Biological Treatment Section

Biological Treatment Process Improvements

Federal Secondary Treatment Standards promulgated in August 1973 define secondary treatment as 85% removal of BOD and suspended solids or as having an effluent with no more than 30 mg of BOD and suspended solids per liter on a monthly average basis, whichever is less. There are over 16,000 municipal secondary treatment facilities in the country, many of which have either become overloaded during their lifetime or were initially designed as high-rate systems and are now incapable of meeting the Standards. These facilities along with the approximately 2,500 existing primary treatment plants offer an excellent opportunity to utilize technological innovations and process modifications as upgrading tools. The paramount objective of biological treatment process improvements is to develop and demonstrate a reservoir of cost-effective upgrading alternatives that will provide the required improvements in plant performance while maximizing use of existing structures and equipment in the upgrade schemes.

The single most significant occurrence in activated sludge technology in the past half decade is the development of cost-effective systems for substituting oxygen gas for atmospheric air to supply dissolved oxygen. Early work in this area was supported by the Biological Treatment Section and several versions of the oxygen-activated sludge process are now being marketed. Presently, oxygen systems are being used primarily for expansion from primary treatment to secondary treatment. Utilization of the process to convert existing overloaded activated sludge plants to oxygen aeration is seen as an important future upgrading technique. Over 50 oxygen-activated sludge plants with a combined daily capacity in excess of 4 million m^3 (2 billion gal) are either in operation or are in design and construction stages.

Options available for upgrading trickling filters include substituting one of several synthetic-media types for the conventionally used rock-media to provide greater surface area for biological growth and improved oxygen transfer, adding metallic salts and polyelectrolytes to either primary or secondary clarifiers to improve solids capture and precipitate phosphorus, and employing a second stage of biological treatment downstream of the existing rock-media filter. The latter technique allows the existing trickling filter installation to act as a roughing unit and often lowers the organic loading on the second stage to a level permitting nitrification to take place. Several reports are already available on the use of chemical additives to upgrade trickling filters at EPA supported demonstrations.

The rotating biological contactor (RBC) has been accepted in Europe, but only recently has significant interest been noted in this country. EPA projects have been initiated to evaluate this process on the weaker wastewaters of the United States. The RBC appears to offer an alternative to the more conventional secondary treatment processes, particularly for smaller plants.

Nutrients in Wastewater

During the current year, all demonstration projects on phosphorus removal technology were completed. All relevant chemical and engineering parameters are now documented to the extent that chemical control of phosphorus can be instituted at any treatment facility operating at design loadings.

This demonstration program has clearly shown that there are three levels of residual effluent phosphorus that should be considered in regard to cost. At the 40,000 m^3/day (10 mgd) size, the following generalization can be made in relation to the capital cost of conventional activated sludge treatment. A phosphorus residual of 1 mg/l would increase capital cost 5% to 10% to provide chemical storage tanks and dosing systems. A requirement of 0.5 mg phosphorus/l would increase capital cost 15% to 20% because provision for media filtration of the effluent would be necessary. If very low phosphorus residuals are required, such as the less than 0.005 mg phosphorus/l at Ely, Minnesota, tertiary lime treatment would be required and the increase in capital cost would exceed 100%.

Studies of the effect of disinfection of secondary activated sludge effluent (under a grant with the City of Wyoming, Michigan) indicate that several alternative chemical disinfectants can be used on municipal wastewater effluents to achieve the secondary effluent standard of 200 fecal coliforms per 100 ml. Companion fish toxicity studies on chlorinated and dechlorinated effluents indicate that residual fish toxicity of chlorinated effluents can be eliminated by sulfur dioxide dechlorination.

Physical-Chemical Treatment Section

Because of its unique properties and capabilities in treating wastewater, activated carbon has merited the major share of research efforts this past year. Research on carbon has revealed additional properties and improved methods for employing carbon that further extend its usefulness for treating wastewaters.

Previous work conducted by the Eimco Corporation at Salt Lake City demonstrated that powdered carbon used in a two-stage counter-current contacting system was capable of producing excellent quality effluent from chemically clarified raw wastewater.

Performance of granular activated carbon contactors in terms of organic loading and effluent quality is related to the effectiveness of the chemical clarification, which usually precedes carbon treatment. Thus, when choosing the chemical, one should consider the degree of organics removal in addition to other factors. A study of three clarification processes (iron, lime at low pH with iron and lime at high pH), showed that iron as ferric sulfate achieved a superior removal of organics; this in turn, reduced the cost of subsequent carbon treatment.

Although activated carbon can adsorb a wide variety of organics, it is generally recognized that adsorption capacity varies with the structure of the organic compound. To assess this variability, the Physical-Chemical Treatment Section has been studying the treatability of toxic organic compounds by a system of coagulation-carbon adsorption. Selection of compounds was based on (a) annual quantity produced, (b) toxicity to humans or fish, or concentration producing other adverse effects in water, (c) probability of occurrence in wastewater, and (d) persistence in water. Bench-scale data have been obtained on some 40 synthetic organic compounds. As anticipated, adsorption capacity has ranged from as much as 2,200 mg/g for nonyl phenol to no detectable adsorption for cyclohexanone or diethylene glycol. The study has been extended to include assessment of treatability by a continuous-flow system treating raw wastewater spiked with the organic compound. Preliminary data for dimethyl phthalate indicate that the chemical clarification system is removing 60% to 70% and that very low residuals, on the order of 1 to 20 μg/l, are being obtained in the carbon effluents. Samples are analyzed by gas chromatography, which provides the required sensitivity and specificity and also enables a judgment on any changes that might occur in the organic molecule during treatment.

Chemical clarification can obtain high removals of most metals by precipitation, adsorption, and filtration, but residual concentration can be in excess of the stringent requirements for reuse. Carbon adsorption can provide the additional metal removal needed to meet standards. Some 12 metals were evaluated in a pilot-scale treatment system consisting of ferric chloride coagulation, filtration, and granular carbon adsorption. Greater than 99% removals were observed for mercury, beryllium, tin, vanadium, and silver; greater than 90% removals were observed for titanium, bismuth, and molybdenum; greater than 85% for selenium and antimony; and greater than 50% for thallium and cobalt. Preliminary results with high pH lime show removals greater than 98% for titanium and bismuth, 75% for selenium, and 60% for antimony.

Removal of ammonia by either biological or by physical-chemical methods is a complex and costly process. The technical feasibility of a new selective adsorbant for ammonia was investigated. Zirconium hydrous oxide, an inorganic ion exchanger, is used as the base material for copper ion, which is attached as the counter ion. Contact with wastewater results in removing ammonia by forming the copper-ammonium ligand. When exhausted, the exchanger is regenerated by low-pressure steam. Further development of the process is being done under contract.

Ultimate Disposal Section

The Ultimate Disposal Research Section is concerned primarily with the sludges produced when treating municipal wastewater. Because of the concern for the accumulation of trace elements and other potentially toxic materials in the environment and a desire to quantify the environmental impact caused by sludge disposal, a program was carried out in which composition of sludge from various parts of the United States was determined. Sludges from 33 municipal wastewater treatment plants were analyzed for 20 metals, nitrogen, phosphorus, and sulfur. In some cases, content of trace metals was high enough to preclude certain disposal options. Proper planning and implementation of sludge disposal operations depend on knowing the composition of sludge.

Aerobic stabilization was studied on a plant scale at Denver. The study showed that aerobic stabilization is a feasible alternative to anaerobic digestion for reducing the volatile solids content of sludge. Pilot plant studies show that with a specially designed aerator and the use of pure oxygen as the oxygen source, aerobic stabilization could be carried out in open tanks. An optimum system for the lime stabilization of municipal sewage sludge has been developed and evaluated. Lime doses and contact times required to eliminate the pathogenic bacteria and odors from a raw sludge were determined by laboratory studies, and translated into design and operational parameters for a pilot-scale plant. Soil and crop studies performed in greenhouses and on controlled outdoor plots indicated that chemicals added for phosphorus removal did not diminish the fertilizer value of the sludge. Sludge was effectively stabilized by adding lime to raise the pH above 12.0 and maintaining this pH for at least 30 min. Air sparging the lime sludge system provided better mixing than mechanical methods and resulted in an approximate 50% reduction in sludge ammonia concentration. An average of 150 g of slaked lime was needed to stabilize 1.0 kg of sludge solids. Total cost for lime stabilization was estimated to be approximately $10/metric ton. Improved sludge thickening rates were an additional benefit of the lime addition.

Anaerobic digestion of sludge kills most but not all of the pathogens and parasites that can be harmful to man and animals. Recent laboratory and pilot-scale research demonstrated that pasteurization of digested sludge at 70°C for 30 to 60 min reduces remaining pathogenic organisms to nondetectable levels. Methane is normally available from anaerobic digestion to meet fuel needs of the pasteurization process. Direct steam injection and efficient mixing of the steam and liquid sludge are recommended for effective pasteurization. If gas from anaerobic digestion is not available, fuel will cost about $10/ton of sludge solids for small plants. Cooling the pasteurized sludge to 60°C is sufficient to permit its use on grasses.

Removal of phosphates from wastewater results in more sludge with dewatering characteristics different from those of conventional digested sludge. A "Task Force Report on Phosphate Removal Sludges" (being prepared) summarizes information on the dewatering properties of sludges produced when aluminum, or iron salts, or lime is added to wastewater to remove phosphate. Information is adequate for lime sludges but is scant for sludge produced by aluminum or iron salt addition. Because these latter sludges present serious dewatering problems, our research has concentrated on characterizing these sludges and improving ways to dewater them.

AWTRL personnel have worked closely with Technology Transfer personnel in preparing a design manual that presents a contemporary review of sludge processing technology and the specific procedures to be considered, modified, and applied to meet unique conditions. The manual—distributed at the Water Pollution Control Federation's 47th Annual Conference—emphasizes the operational considerations and interrelationships of the various sludge treatment processes to be considered before selecting the optimum design.

Sludge Disposal

Although the amount of sludge produced in publicly owned sewage treatment works is increasing, the options for disposing of sludges are not increasing. Each of the commonly used disposal methods—land spreading, landfilling, and incineration and landfilling of the ash—is being reexamined to improve the technology and ensure against risks to the environment or the public health. Reduced energy consumption and increased cost effectiveness are also desired.

A review of liquid sludge spreading practices in the United States, conducted by Battelle Memorial Institute (Columbus, Ohio) shows that sludge had been used as a fertilizer and soil conditioner for many years with apparent success. In the last 10 yr, the use of sludge spreading as a disposal practice rapidly increased because of its simplicity and low cost for many municipalities. Farmers generally accept the sludge because of its effectiveness in increasing crop yields. The survey also indicated that the effects of sludge addition on soils, crop composition, and water and air quality had not been adequately monitored.

Chicago is conducting a large research and demonstration project to develop and evaluate methods for applying sludge to cropland in central Illinois and for reclaiming strip mine spoils. Almost 200 tons of Chicago sludge solids per acre have been applied without causing trace element toxicity to general farm crops. Tissues and organs of pheasants fed with corn grown on sludge-amended soil showed no evidence of adverse changes.

Some form of landfilling is the most frequently used wastewater sludge disposal method. Many landfills, however, do not meet the standards of a sanitary landfill. A study of landfilling with sludge by a trenching method is being developed and evaluated under an interagency agreement with the USDA Agricultural Research Service at Beltsville, Maryland. Previous experiments with placing up to 500 tons of sludge solids per acre in shallow trenches showed that soil could be improved without polluting the environment with excessive nutrients, trace elements, or pathogens. Conventional farm equipment is now being used to entrench sludge and to demonstrate a feasible disposal method for small communities.

Many officials, lacking adequate information on sludge disposal methods, are unable to choose the most cost-effective one for a particular set of circumstances. Several conferences and workshops were supported by AWTRL to supply as much of the information as is available. The EPA cooperated with the USDA and land grant universities in conducting a workshop to identify the state-of-the-art of landspreading municipal sludges and effluents and describe research needed to improve the technology. Other symposia on sludge disposal were held at Rutgers University and in Pittsburgh; proceedings of all conferences have been published. These publications represent an effective way of quickly providing the wastewater treatment field with the latest research results.

SYSTEMS & ENGINEERING EVALUATION BRANCH

Storm & Combined Sewer Section

Assessment

Over the past decade much research effort has been expended and a large amount of data has been generated in the area of control, or treatment, or both of storm sewer discharges and combined sewer overflows. Much of this work has been accomplished through the actions and support of the Storm & Combined Sewer Section. A comprehensive investigation and assessment of projects representative of abatement theory and technology was published. This publication is a compendium of project information on management and technology alternatives useful for decision-makers, whether they be engineers, administrators, or members of the concerned public.

To enhance professional and public awareness of the storm-water problem and the abatement techniques available and presently being investigated, a 30-min narrated documentary color film, "Stormwater Pollution Control: A New Technology," has been produced. This film portrays a complete overview of the EPA's involvements in developing countermeasures for pollution from combined sewer overflow and stormwater discharges.

Simulation Models

System control aims to optimize the containment and treatment of stormwater runoff with actions dependent upon the storm pattern, treatment and storage availability, and projected system behavior. When overflows to receiving waters prove necessary, quality monitoring, coupled with system controls, permits the releases to occur in the least damaging manner. The smaller the storage volume and the more variable the rainfall pattern, the more critical the monitoring and control system become. Mathematical models can play an important part in developing and fine-tuning these systems. In Seattle, advanced computer control techniques have been successfully applied to reduce combined sewer overflows. Fifteen regulator stations and one major pumping station were controlled to reduce overflow volumes by 50% to 60% under supervisory control and by more than 90% under automatic program control during unusually dry weather. All stations are monitored and capable of remote supervisory operation from a central control console (Figure 18).

Battelle Northwest evaluated 18 mathematical models simulating dynamic wastewater flow and

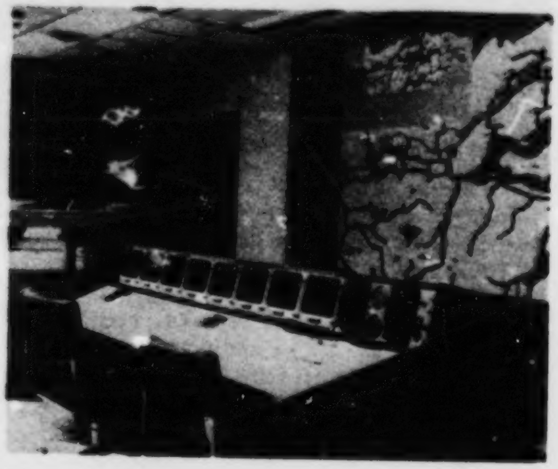


Figure 18. Central control console for combined sewer flows in Seattle, Washington.

quality conditions. Their survey will provide engineers and planners with a single reference, containing brief but precise descriptions and evaluations of all the models studied. Modification and improvement of the EPA Storm Water Management Model (SWMM) is continuing. The University of Florida has completed their work on "Release 2" of the SWMM, which includes additional program components. The SWMM has been made available to communities lacking modeling capabilities. Such a service provides for the availability of the computer program itself in several easy-to-use modes and technical assistance in problem delineation, data reduction, debugging, and output interpretation. A mathematical modeling seminar was conducted at the University of Massachusetts to familiarize Federal, State, local, and consulting engineers with the overall concept and availability of stormwater models.

Treatment and Control

At the Borough of New Providence, New Jersey, the treatment plant designed to handle wastewater from a sanitary sewer system subjected to excessive infiltration uses two high-rate filters—one with rock media, the other with plastic media. During dry weather, the two units are operated in series with the plastic media acting as a roughing filter ahead of the rock. This provides an active biological slime on both filters. When excess infiltration flows hit the plant, the mode of operation is switched automatically from series to parallel, roughly doubling the effective treatment capacity. Removal efficiency is 85% to 95% for both BOD$_5$ and suspended solids during dry-weather flow and 65% to 90% during wet-weather flow.

The Philadelphia Water Department completed the third phase of work conducted to confirm the performance of a microstraining unit (Figure 19) and the effectiveness of disinfection at high rate with chlorine. The microstrainer, stainless steel screen with 23-μ openings, reduced the suspended solids of the combined sewer overflow to 40 to 60 mg/l from initial values up to 300 mg/l. The addition of polyelectrolyte improved the overall performance of the microstrainer—reducing the effluent suspended solids to an average of 23 mg/l, while more than doubling the influx rates. They also found that microstrained effluent could be more easily disinfected than the raw combined sewer overflow.

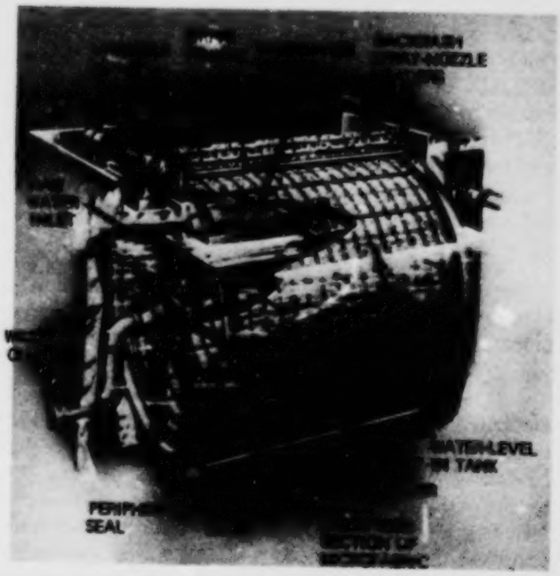


Figure 19. Cutaway diagram of a microstrainer used to remove suspended pollutants from storm waters.

Municipal Treatment and Reuse Section

Systems Demonstration

The first physical-chemical treatment plant began operation at Rosemount, Minnesota, in January. The treatment train consists of screening, single-stage chemical clarification, dual-media filtration, carbon adsorption either downflow or expanded-bed upflow, filtration, and specific ion-exchange for ammonia removal. Preliminary data obtained during plant start-up and shakedown have demonstrated that the effluent quality meets the standards of 10 mg/l BOD, 10 mg/l suspended solids, 1.0 mg/l total phosphorus, and 1.0 mg/l ammonia nitrogen (Figures 13-14).

At Ely, Minnesota, the half-way point in the 3-yr study of lake restoration by phosphorus control has been passed. Total effluent phosphorus in the tertiary plant effluent has averaged 0.043 mg/l for the first 18 mo of the study. Plant reliability has been excellent, and the total phosphorus entering the lake has been reduced by 70%. Both the concentrations of phosphorus and chlorophyll *a* in the lake are significantly less than in recent years and qualitative observations of the lake in the fall of 1974 indicated a much reduced algal bloom over previous years.

Methods and Processes to Improve Operation and Maintenance

Research into methods and processes to control sulfide generation in wastewater collection systems has culminated in the publication of a sulfide control manual describing both design methods to prevent sulfide occurrences and control technology to eliminate problems in existing systems. A full-scale flow equalization project at Ypsilanti Township (Michigan) utilizing two parallel 18,000 m^3/day (4.5 mgd) activated sludge plants indicates a significant reduction of concentration fluctuations is occurring in the flow equalization basin. Comparison of equalized performance of one plant with background (unequalized) data collected during the construction phase of the project indicates significant improvement in removal efficiency and reliability.

Small Flows

On-Site Wastewater Management. The characterization portion of a comprehensive research grant (University of Wisconsin) to study individual home wastewaters indicates that water usage is less than 190 l (50 gal)/person per day. Because of wastewater flow variations and high pollutant concentrations, treatment methods provide generally poor removals. Under this grant, soil disposal system designs will be developed and methods of regulatory control to optimize these systems will be formulated.

Advanced Collection Technology. Pressure sewer demonstration projects have documented much of the necessary design and economic information necessary to make pressure sewer systems available for general use as an alternative to conventional gravity sewerage. In most rural areas, construction costs are only a fraction of those for the conventional systems. In most rural locations the initial cost of pressure sewerage is less than $1,500/home, whereas, estimates for conventional gravity sewers often exceed $10,000/home. Additional benefits include low or no infiltration, which results in smaller treatment facilities.

Municipal Wastewater Reuse

The performance and reliability of advanced wastewater treatment (AWT) systems to remove pollutants and the potential health effects associated with the reuse of municipal wastewater are the primary concerns of the reuse program. To provide needed information in these areas, AWTRL and the Water Supply Research Laboratory initiated a cooperative project to measure the parameters of water quality that are related to potability in effluents from AWT plants. A part of this study will be to identify key components and evaluate the toxicity of concentrates from the AWT effluents and compare them with similar concentrates from approved potable water supplies. The AWT systems are located at Lake Tahoe, Orange County, and Pomona (California); Dallas (Texas); and Washington, D.C. (EPA–DC Pilot Plant). Effluents from these systems are being examined for organic materials, heavy metals, pesticides, viruses, and radioactivity.

A completed survey of municipal wastewater reuse in the United States indicated that about 1.6 million m^3/day (0.4 bgpd) of effluent is being directly reused, primarily for agricultural and industrial purposes. This is less than 5% of the water resources available for reuse via the Nation's municipal effluents.

The use of renovated wastewater for establishing aquatic recreational facilities in water-short desert areas is being demonstrated at Lancaster, California. A system composed of alum coagulation, sedimentation, mixed-media filtration, and chlorination treats the effluent from the wastewater treatment plant's oxidation pond, which then provides water for the 56-acre Apollo County Park shown in Figure 20. The three lakes in the park contain 80 million gal of renovated wastewater and are used for sport fishing and boating by the general public.

TECHNOLOGY DEVELOPMENT SUPPORT BRANCH

Systems and Economic Analysis Section

The time-dependent behavior of the activated sludge process has been studied by means of a digital computer program. Significant savings in electrical power for supplying air to the process are possible when the dissolved oxygen concentration in the aerator is measured continuously and this measurement is used to modulate the air supply. The sludge inventory, however, responds so slowly to changes in the sludge wasting rate that laboratory measurements are adequate to control the sludge inventory. The cost of alternative sludge handling schemes was studied with the use of an

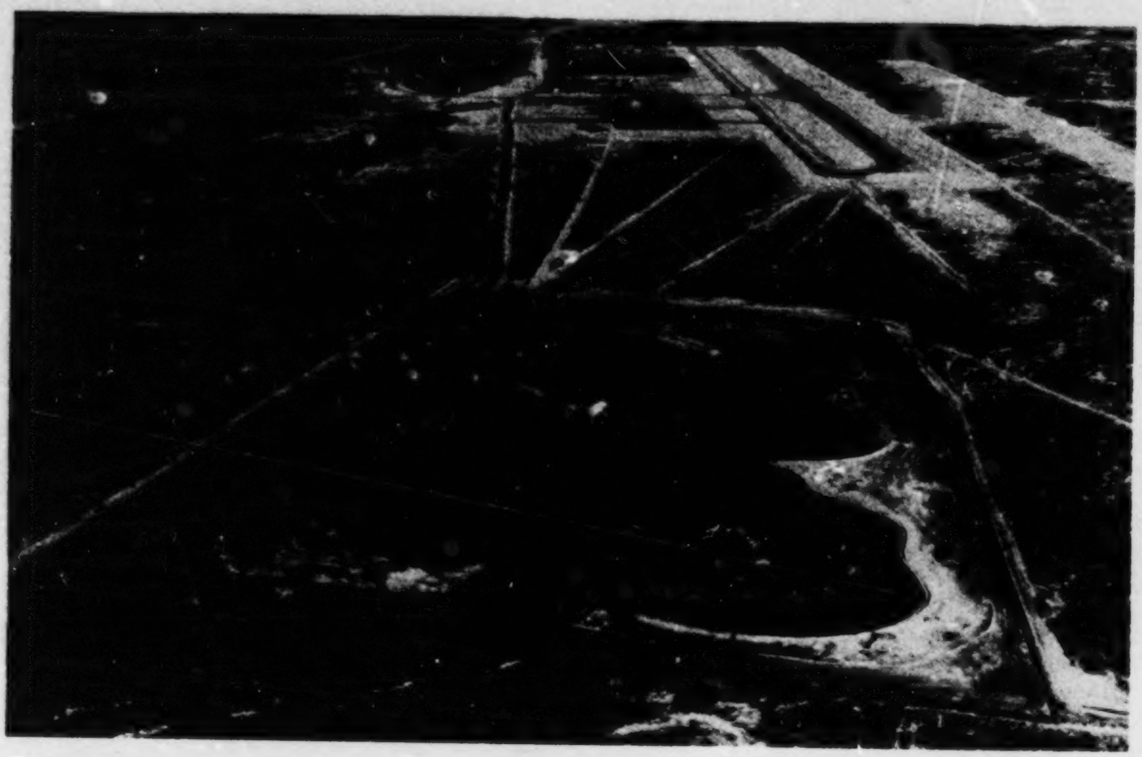


Figure 20. Recreational lakes in the Mojave Desert filled with renovated water from Lancaster, California.

executive computer program. The least costly schemes usually involved anaerobic digestion, followed by sludge drying beds, and finally, application to farm land.

The total cost of supplying dissolved oxygen to wastewater was studied, and mechanical aeration was found to be the least expensive in terms of cents per pound of pure oxygen dissolved. The cost of generating and dissolving pure oxygen was similar to the most costly diffused air system. Other cost savings arising from the use of pure oxygen, especially capital savings from an increase in existing plant capacity, can nevertheless justify the use of pure oxygen as discussed in the Biological Treatment Section.

Pilot and Field Evaluation Section

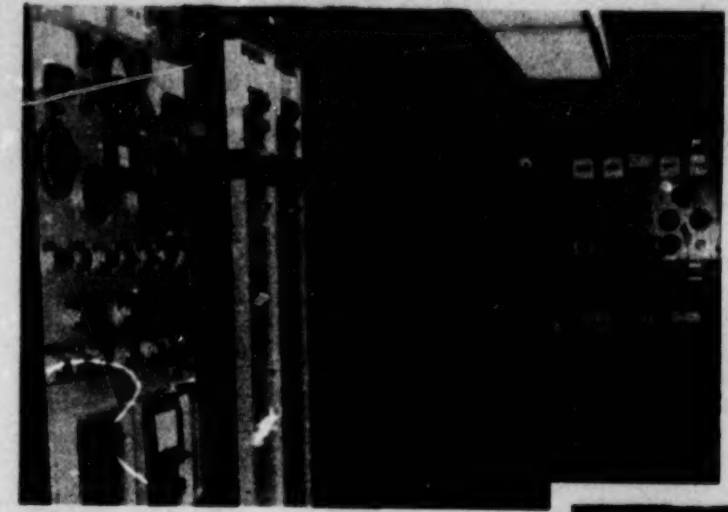
Biological work at the EPA–DC Pilot Plant included studies to characterize the performance of three parallel modes of operation of the activated sludge process ("plug flow," step, and completely mixed aeration) over a wide range of operating conditions (sludge retention time, SRT, or food to mass of sludge ratio, F/M). At low SRT, a bulking filamentous (*Sphaerotilus*) sludge was produced; at high SRT, *Nocardia* bulking predominated.

In pure oxygen systems at the EPA–DC Pilot Plant satisfactory nitrification was achieved with and without pH control with typical residual ammonia concentrations of less than 1 mg/l. Comparison of pure oxygen nitrification with air nitrification on the same wastewater at the same pH did not reveal any significant differences in the nitrification kinetic rates.

Physical-chemical treatment of the raw wastewater at the D.C. pilot plant consisted of low lime coagulation with iron salts, pH control with carbon dioxide followed by parallel operation of filtration ahead of granular carbon adsorption and granular carbon adsorption ahead of filtration. The two variations produced similar effluents with typical residuals of 0.5 mg phosphorus/l, 12 mg BOD_5/l, and 3 to 4 mg suspended solids/l. Breakpoint chlorination ahead of the carbon columns produced average total nitrogen residuals of about 2 mg/l. The low lime — iron salt sludge could be dewatered by vacuum or pressure filtration or by centrifugation. Aerobic digestion of this alkaline sludge produced 40% to 45% volatile solids reduction without any pH adjustment of the sludge feed.

At the Pomona Pilot Plant, the use of ozone to remove coliforms and bacteria from secondary effluent was studied on a small scale. Filtration ahead of the ozonation system was essential. Doses of ozone to reduce color below 10 units were moderate—10 to 15 mg/l. Doses to reduce coliforms (MPN) to less than 2.2/100 ml were very high—40 to 50 mg/l.

At the Lebanon Pilot Plant tube settler performance on the 6,000 m^3/day (1.5 mgd) overloaded activated sludge plant was evaluated. The tube settlers produced a 100% improvement in effluent quality in a direct parallel comparison against a conventional gravity clarifier. Three methods for treating septage pumped from septic tanks were evaluated. Aerobic digestion successfully stabilized the septage. Lime stabilization using 100 kg (200 lb) calcium oxide per ton (dry weight) of treated septage removed essentially all fecal bacteria. Chlorination with chlorine doses of 1,000 to 2,000 mg/l provided complete stabilization and disinfection. Sand-bed dewatering of the lime-stabilized septage needed 14 days to reach 25% solids whereas chlorine-treated solids needed only 2 days to reach more than 30% solids.

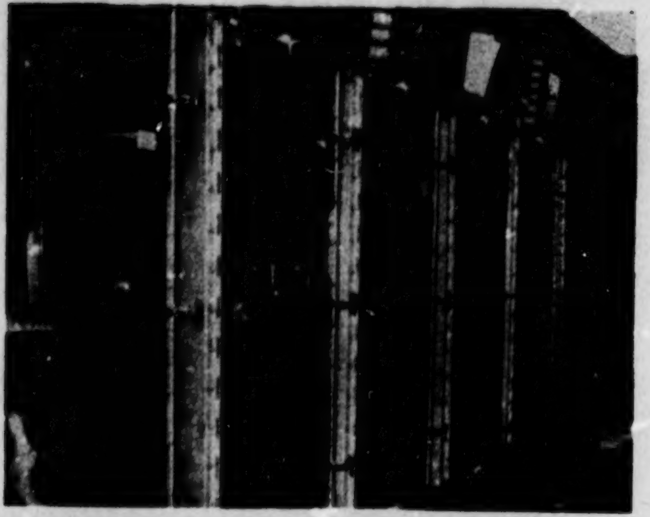


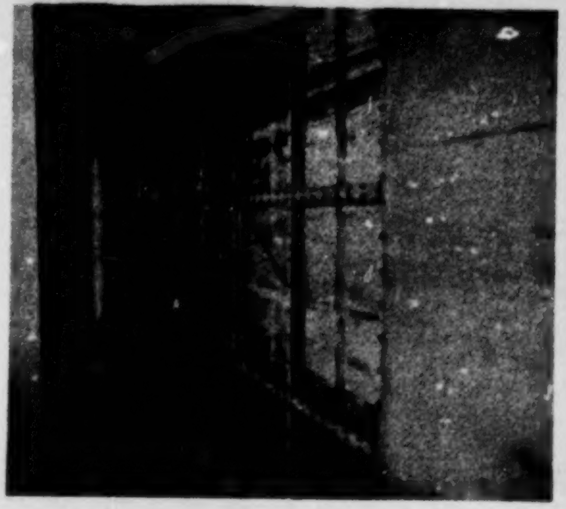
Through an electronically programmed set of urban driving conditions, the console (Figure 21, top) "drives". . .

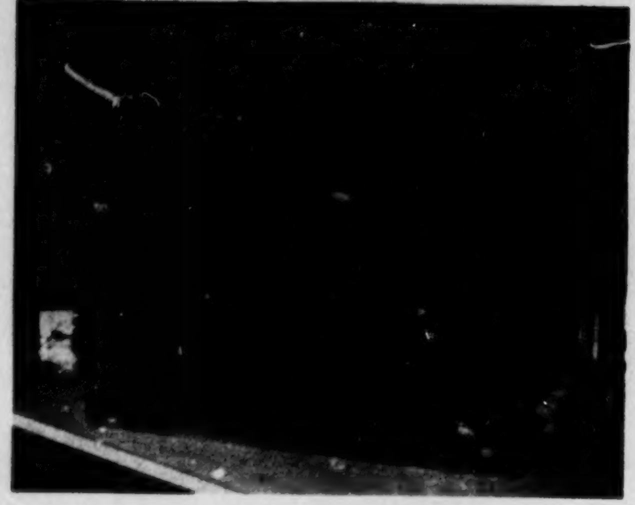
automobile engines (Figure 22, center left) equipped with catalytic converters in the exhaust system. The engine exhausts are then processed to represent various atmospheric conditions. . .

as, for example, by irradiating (Figure 23, bottom left) the exhaust with simulated sunlight to create smog by photochemical reactions. The resulting atmospheric automobile pollutants are then transported to sealed chambers, such as in Figure 24 (center right), where inhalation exposure takes place under carefully controlled conditions. . .

to study toxicologic and behavioral effects; in Figure 25 (bottom right), blood pressure is being studied.







environmental toxicology research laboratory

INTRODUCTION

The Environmental Toxicology Research Laboratory (ETRL) is required to test, evaluate, and define potential harmful effects of environmental pollutants from mobile and stationary sources. The objectives of this research are based on the legislative mandates of the Clean Air Act of 1970, as amended, specifically Sections 103(a) and(f); 104(a); 202(a); 204(a); and 211(b). The data obtained in experimental biological models, particularly in mammalian species, provide necessary input for the development of criteria documents; these in turn, serve to establish realistic environmental standards.

The ETRL program has been organized to emphasize the toxicologic assessment of automotive emissions originating from oxidation catalysts and of the catalytic attrition products. The catalysts are designed to reduce the concentrations of carbon monoxide and hydrocarbons in the exhaust stream by oxidizing them into carbon dioxide and water. The control of the concentrations of carbon monoxide and hydrocarbons in automotive emissions is necessary for light-duty vehicles to comply with the emission standards set forth in the Clean Air Amendments of 1970.

With the use of palladium and platinum in automotive catalytic converters, some of the material may possibly be emitted to the atmosphere or enter into other segments of the environment following degradation or disposal of worn-out converters. It can be speculated that the attrition products from the catalyst could include particulate composed of the metals combined with substrate material, and different chemical forms of palladium and platinum.

Little information existed on the toxicology of the chemical forms of platinum or palladium that might be expected to occur following use of these metals in the catalyst, and there was no information on the inhalation exposure of animal systems to exhaust from automobiles containing a catalyst in the exhaust train.

Because ETRL has been studying the biological effects of the noble metals for only a short time, the data should be considered preliminary since the total impact of any metal upon a biological system and on the biosphere is complex. These findings should serve as a basis, however, for additional research in defining the impact of the use of these metals on the environment.

The major potential public health problem concerned with the use of catalysts—the one that appears to have received the greatest amount of attention in the technical and lay press—is the potential emissions of sulfuric acid and sulphate particulates, especially an increased level of these pollutants, in instances when high sulfur gasoline is used. It is hypothesized that a buildup of sulfates may occur in heavy traffic areas by catalyst-equipped automobiles, particularly where meteorologic and topographical conditions do not allow for a rapid dispersion of the pollutants. The ETRL has published a summary report on the toxicology of atmospheric sulfur dioxide decay products and on catalytic components and exhaust emissions. Several specific toxicologic investigations on sulfates including a chronic study at realistic pollutant levels are ongoing.

In Fiscal Year 1974, the ETRL effort was divided into two major segments: (1) assessment of the biological effects of automotive emissions that have passed through the oxidative catalytic converter; (2) toxicological studies on noble metals. In the current bioeffect studies of noble metals associated with the oxidation catalyst, the soluble forms of palladium and platinum were used to ascertain some of the basic toxicological and metabolic aspects. In addition, since it must be realized that the availability and metabolism of other chemical forms or substrate material containing palladium or platinum may be different, other such pertinent studies are in process.

In addition to the investigations of catalyst emissions and their components, during 1974 ETRL conducted several other in-house projects, e.g., the assessment of physiological availability of various chemical compounds of lead, and the acute toxicity aspects of a potential antiknock rare earth fuel additive tetrakis (2,2,6,6-tetramethyl 1-3,5-heptandionate) cerium ($Ce(the)_4$).

TOTAL EMISSION STUDIES

Measurements of Exhaust Emissions With and Without Catalytic Converters

The design for toxicologic studies of emissions with and without a catalytic converter requires precise aerometry measurements of the atmospheres to which experimental animals are exposed. The reason for the use of the catalytic converter in the automobile exhaust train is to meet emission standards for carbon monoxide and hydrocarbon as set forth in the Clean Air Amendments of 1970.

Early studies indicated that oxidation-type catalysts in auto exhaust systems generated significant levels of sulfuric acid aerosol—up to 0.1 g/vehicle mile. It was hypothesized that engine combustion converted the organic sulfur compounds in the gasoline into sulfur dioxide, which was further oxidized by the catalyst to sulfur trioxide, which reacted with water vapor in the exhaust to produce sulfuric acid aerosol. The engine used in these studies was a 1973 Chevrolet 350 C.I.D. production model with exhaust gas recirculation, air pump, and turbo hydromatic transmission coupled to an "eddy current" absorption dynamometer. The pelletized noble metal oxidation catalyst was a product of Engelhard Mineral and Chemical Company. During the animal exposure study phase, the engine was cycled continuously (24 hr/day) for 1 wk on the "California" 7-mode cycle. The average concentrations of the various exhaust emission components in the animal exposure chamber are shown in Table 3.

It was evident that the catalyst successfully removed carbon monoxide and hydrocarbons under the hot cycling conditions. The percent concentration reductions of exhaust emissions as a result of installing the catalytic converter, after normalizing dilution ratio and averaging exposure chamber data, are summarized as follows:

CO	93%
THC	80%
Aldehydes and acetylene	99+%
Olefins	93%
Aliphatics	59%

Acute Biological Effects of Exhaust Emissions With and Without Catalytic Converter

Adult male outbred albino rats and adult male golden Syrian hamsters were exposed to the various treatment atmospheres. Tissues were collected, processed, and examined microscopically for evidence of morphologic changes attributable to the exposure.

There were no treatment-related changes in the studies with a catalyst. Without a catalytic converter, however, there were extensive pulmonary changes that were more severe in hamsters and most severe in those animals exposed to irradiated exhaust. In the nonirradiated exhaust group, the pulmonary changes were relatable to the levels of nitrogen dioxide: initially, an increase in alveolar macrophages at the level of terminal bronchioles, followed by a proliferative phase with some apparent increase in epithelialization of respiratory ductules and in thickness of alveolar septae. In the hamsters exposed to irradiated exhaust, there was a very severe acute purulent bronchitis and bronchiolitis that progressed to a subacute purulent bronchopneumonia by the end of the study. Additionally, there were some degenerative changes in renal and hepatic tissue after 5 days of exposure of these animals. The only lesion that could be solely related to carbon monoxide levels was extramedullary hematopoiesis in the liver of the rats after 4 days of exposure.

Lactating female outbred albino rats and their 2-wk-old offspring were exposed to each of the treatment atmospheres for 7 days. There was prominent infant mortality in those animals exposed to exhaust without a catalytic converter. This was not a carbon monoxide effect alone but rather due to the combination of biologically active pollutants.

TABLE 3. CONCENTRATION OF EXHAUST EMISSION COMPONENTS

		No catalyst	With catalyst	
Emission components	Exhaust	Indolene only	Indolene only	Indolene w/sulfur[*]
Exhaust dilution ratio		9.6/1	8.7/1	9.5/1
CO, ppm	NI[†]	551	46	40
	I[‡]	559	41	38
THC, ppm	NI	110	22	18
	I	95	22	18
NO_x, ppm	NI	11.9	12.9	12.6
	I	5.1	12.6	11.2
NO, ppm	NI	6.7	11.1	10.8
	I	0.5	9.6	9.7
NO_2, ppm	NI	5.2	1.8	1.8
	I	4.6	3.0	1.5
Aldehydes, ppm	NI	10.20	0.08	0.18
	I	14.62	0.10	0.11
Aliphatics, ppm C_4–C_8	NI	1.30	0.61	0.44
	I	1.32	0.58	0.39
Olefins, ppm C_2–C_4	NI	13.24	0.89	0.91
	I	9.23	0.79	0.82
Acetylene, ppm	NI	3.28	0.03	0.04
	I	3.06	0.03	0.04
Ozone, ppm	NI	0.0	—	—
	I	0.4	—	—
Particulate, mg/m^3	NI	0.77	1.08	9.30
	I	3.59	1.23	8.75

[*] Thiophene added to produce 0.10% by weight sulfur.
[†] NI = nonirradiated exhaust.
[‡] I = irradiated exhaust.

A loss in body weight was noted in the adult and suckling animals. With a catalyst, there were no pronounced treatment effects on either of these parameters.

Adult male outbred albino rats were exposed to each treatment atmosphere. Animals were removed on days 2 through 6 of the study, anesthetized, and exsanguinated by abdominal aorta catheterization. A treatment effect occurred only in the noncatalytic-treated exhaust exposure groups; the more prominent changes occurred in the animals exposed to irradiated exhaust. The high carbon monoxide levels had an effect on the hematologic parameters but was not solely responsible. No treatment effect was noted in studies with a catalyst. Because of the historical association of platinum with allergic responses, it was particularly interesting to note no increased eosinophils in animals exposed to exhaust from the catalyst.

The oxidation catalyst did have an effect on the type of particulate with an increase in the sulfuric acid fraction. There were no demonstrable acute biological effects in the animals studied that might be attributable to the altered particulates. The study did not rule out possible chronic effects due to long-term exposure either as a result of increased sulfate emissions or attrition products of the noble metal oxidation catalyst. It is, therefore, imperative that long-term studies be initiated to provide this additional information.

Effect of Catalyst-Treated Exhaust Emissions and Components on Development and Growth

Pregnant and newborn rats were subacutely exposed to diluted catalyst-modified exhaust in two successive studies. The preliminary results did not reveal clear-cut significant effects of the catalytic exhaust on body weight or growth nor were gross pre- or post-natal developmental defects demonstrated. Thus far, only suggestive evidence of reduced infant survival was obtained in one study. Additional contract studies to investigate embryotoxicology of individual pollutants, such as nickel, palladium, and platinum sulfates, were initiated.

Effects of Exposure to Catalyst-Treated Exhaust Emissions on Pulmonary Free Cells

Animals exposed to catalyst-treated automotive exhaust were used to obtain lavage-recoverable pulmonary cells, primarily macrophages. They were examined for effects with respect to numbers, size, and phagocytic function. In one study, average values for total free-cell yield and the proportion of phagocytic cells were comparatively lower in the irradiated exhaust – exposed group than in controls, whereas average cell size was slightly greater in the exposed vs. control groups. Preliminary evaluation of data from another study indicated a reduction in means of the phagocytotic parameter (the proportion of phagocytic cells, and quantity phagocytized) for exposed animals when compared with control groups, which was in qualitative agreement with previous data; however, the cell populations, on the average, were somewhat increased and the cell size was decreased.

Chemical Characterization and Biochemical Toxicity of Organic and Inorganic Components of Auto Exhaust

In the chemical characterization phase of this project, exhaust sample collection methods were evaluated and metal-binding properties of exhaust condensate material, collected before and after a catalytic converter, were studied. Exhaust samples were found to have significant copper-binding activity, the significance of which is being explored in relation to interaction of exhaust components with metals in biological systems. When the acetone solvent trapping system was compared with the cold-dry trapping system on the basis of copper-binding activity per liter of exhaust sampled, it appeared to be more efficient. Various approaches for better assessment of the mass material balance are being evaluated. An interesting observation was made, however, using the cold-dry trapping system: catalyst-treated exhaust material had greater copper-binding capacity than the pre-catalytic exhaust material. Collection data suggest the feasibility of collecting and fractionating exhaust material for future *in vitro* and *in vivo* biological tests to better define the potential toxic significance of exhaust pollutants. In *in vitro* studies of the effect of metallic compounds on red blood cell aminolevulinic acid dehydratase activity, copper (II) chloride and mercury (II) chloride were 10 to 100 times less inhibitory than bivalent lead ion. Platinum (II) potassium chloride, platinum (IV) potassium chloride, palladium (II) chloride, and methyl mercury (II) chloride were 100 to 1,000 times less active. Zinc ion has been shown to activate aminolevulinic acid dehydratase.

Effect of Exposure to Catalyst-Treated Automotive Exhaust on Lung Microsomal Mixed Function Oxidase Enzyme Function

Because of possible implications with respect to the ability of the organism to process and remove complex inhaled organic materials by biodegradation, or bioexcretion, or both, and their possible relationship to carcinogenic risk, groups of hamsters were experimentally exposed to irradiated and nonirradiated exhaust modified by catalytic muffler and were then evaluated for microsomal mixed function oxidase activity. When the irradiated exhaust group was compared with the controls, enzyme activity was significantly depressed and lung:body-weight ratio was increased. These parameters were not affected in the nonirradiated exhaust group of animals. Previous studies have shown that enzyme depression was of greater magnitude in subjects exposed to exhaust atmospheres not modified by catalytic emission control devices than in those exposed to catalyst-treated exhaust. Although this enzyme system is clearly altered by exhaust pollutants experimentally, toxicologic interpretation with respect to potential health hazard (carcinogenic or other) requires further study.

Catalyst-Treated Automotive Exhaust Exposure and Pulmonary Clearance of Particulate Material

Functional integrity of mechanisms by which inhaled particulate material is cleared from the lungs is extremely important to the well being of the organism. An inert particulate material, titanium dioxide, was used to evaluate clearance function in groups of hamsters exposed to irradiated and nonirradiated catalyst-modified auto exhaust. The test challenge with the particulate was administered after exposing the animals to the auto exhaust atmospheres; and it was followed by serial periodic titanium assay. The pattern of clearance of the test material was altered at day 8: there was increased clearance in the irradiated exhaust group when compared with controls, but no increase in the nonirradiated group. The direction of effect was in general agreement with earlier studies. The toxic significance of this effect, beyond the possible recruitment of defensive clearance mechanisms by irritants, remains to be clarified.

Long-Term Exposure to Automotive Emissions

The long-term auto exhaust and other atmospheric pollutants study in eight groups of experimental animals is being concluded. During the past year of the contract with the University of California, Davis, a final set of hematological and physiological tests were completed; other terminal studies included clinical chemistry analysis, pulmonary function measurements, completion of the cardiovascular effect studies, and pathological tissue assessment. The animals have been necropsied, and the gross pathology and organ weight analysis were completed, as well as total lung collagen measurements. A large number of tissue specimens are being processed by the City of Hope National Medical Center for lipid profile. Pulmonary tissues from selected animals were examined by the Stanford Research Institute by electromicroscopy. The pulmonary morphometric and electron microscopic studies are continuing at the University of California, Davis.

SINGLE POLLUTANT STUDIES

Toxicity Studies of Noble Metals

Platinum and palladium were incorporated into the structure of catalysts used for control of mainly organic components of a toxic nature that are present in auto exhaust emissions. Consideration of these two noble metals for such use stimulated a renewed interest of chemists in the physical and chemical properties of various compounds of platinum and palladium, and of toxicologists in the biological fate of their compounds. Recent studies in this laboratory have identified traces of noble metals in the exhaust, although the composition of the compounds containing platinum and palladium has not yet been determined. It became evident that there were large gaps in the data on the physical, chemical, and biological characteristics of these two metals and that more information was needed in order to determine what impact these metals would have upon the environment.

A number of investigators have described the toxicity of the soluble platinum salts following industrial exposure. The term platinosis has been used to describe the respiratory and/or cutaneous reactions. With the emission of platinum and palladium in the exhaust, the lungs probably serve as the major portal of entry for human exposure. Because very little information is available concerning the biological fate of platinum and palladium following inhalation, current studies were undertaken to provide data on their whole body retention, tissue distribution, and excretion following inhalation of different chemical forms.

Generating Platinum and Palladium Aerosols and Determining Them in Tissue Samples

Techniques of thermogravimetric analysis and pyrolysis in an oxidative atmosphere were used to generate aerosols of individual platinum and palladium compounds of controlled composition, concentration, and size for animal exposure studies. Special handling of samples and modification of standard analytical techniques for atomic absorption spectrophotometric analysis were used to measure trace amounts of platinum and palladium. The atomic absorption method was used for both filter samples of test atmospheres and for tissue specimens taken from animals exposed to such atmospheres or to tracheally instilled or ingested compounds of the noble metals.

Inhalation studies or aerosol-type pollutants require particles of a respirable size, which represents an aerodynamic size of no more than a 5-μ sphere of unit density with a preferable average of about 1-μ. Since the densities of the required compounds —sulfates, chlorides, and oxides—are relatively high, the 1-μ aerodynamic size is equivalent to only one-half or less micron in physical size. For each aerosol generated, a nebulizer was used to produce the dispersion of the compound from an aqueous solution. Platinum sulfate, for example, was aerosolized from a liquid of a specific concentration calculated to yield final solid particles averaging 1-μ in diameter (aerodynamic size). The aqueous droplets were passed through a drying tube, and the dried particles were exposed to a radioactive ionizing source to "neutralize" the charges on the particles. By appropriate dilution with clean, dry air, the aerosol was introduced into the animal exposure chamber to render a final mass concentration of, say, 7 mg/m^3. Filter samples were taken to check the mass concentration. Particle size was determined by previous calibration. When radioactive isotopes of the metals were used, a scanning count of the filter provided an additional check on the concentration of compound in the test atmosphere. Platinum oxide aerosol was produced by nebulizing a solution of platinum sulfate, drying the droplets in a heating tube, pyrolyzing the solid particles at 600°C to produce the oxide. The oxide was then directed to the animal exposure chamber through a carbonate-coated tube that removed the acidic gaseous components. Platinum metal aerosol was produced from a starting solution of platinum chloride that was treated by the same process as the platinum sulfate mentioned above. An activated carbon tube was used to remove the active gaseous components from the aerosol atmosphere entering the exposure space.

Platinum and palladium in tissue specimens were measured by atomic absorption spectrophotometry; application of the flameless technique with the use of a graphite furnace improved the detection level. The analytical method involved a wet digestion procedure that employed nitric acid, aqua regia, and hydrochloric acid at different intervals during the digestion procedure. The digested sample was diluted with water before being introduced into the graphite furnace. The furnace parameters, along with the normal standard curves, recovery studies, and detection limits, were investigated to render optimum conditions for measurement of trace amounts of two noble metals. Key points in the quantitation of the platinum or palladium involved (1) using aqua regia and sodium chloride to promote conversion of all the metal to the chloride form in the wet digestion, (2) not permitting the samples to go to dryness in the later stages of digestion, and (3) using the graphite furnace to improve detection by an order or two over the flame technique (lower limits of detection of total platinum and total palladium in 1 g of tissue were 0.20 and 0.17 μg, respectively). Thus, a method was developed for routine analysis of platinum and palladium in tissue samples in the parts per billion range.

Whole body retention of ^{191}platinum in rats following a 30-min inhalation exposure to two different platinum compounds is shown in Figure 26. Tissues containing the highest concentrations include the lungs, kidney, and liver. The noble metals are excreted in both urine and feces.

Cardiovascular and Pulmonary Studies

The use of the catalytic converter imposed the need for more precise health effects data concerning platinum and palladium than currently exists in the literature. For this reason, we are examining the acute toxicity of these heavy metals on cardiovascular system in surgically prepared unanesthetized rodents. Thus far, our findings have shown that palladium (as $PdSO_4$ solution), when given intravenously, routinely produced mild episodes of cardiac arrhythmias in doses of 0.6 mg/kg body weight in rats, whereas serious arrhythmias often culminating in death were seen with a dose of 0.75 mg/kg body weight. Investigations involving lesser doses as well as additional soluble palladium compounds are underway. In addition, we have found that pulmonary function of guinea pigs remained unaltered during and following a 90-min exposure to an atmosphere containing a platinum chloride aerosol of 1.1 mg/m³ with a 1-μ diameter particle size.

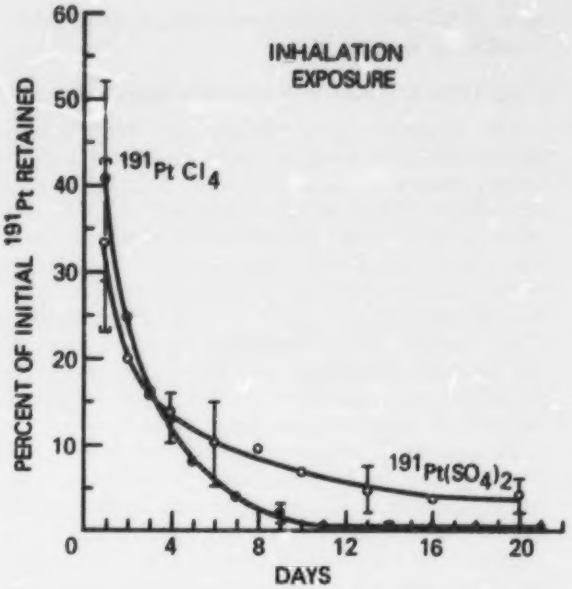


Figure 26. Whole body retention in rats following acute inhalation exposure.

Neurophysiology and Behavior Studies

Neurophysiological and behavior experiments are being utilized as a method of determining the potential toxicological effects of various environmental pollutants on general and specific central nervous system function. Studies using the rat visual evoked potential as a rapid screen to assess the potential neurotoxic effects of several heavy metals, which might be released to the environment from mobile or stationary sources, have been completed. Other more quantitative techniques have been developed by using computer averaging and frequency analysis, which allows the assessment of the effects of environmental pollutants on the spontaneous electroencephalograms. Contracts on the effects of the heavy metals on spinal cord reflexology have shown that lead and other metals may lead to decreased transmission between various types of spinal neurons. In addition, other contractual behavior studies have shown that lead exposure may result in a decreased ability to discriminate. Studies such as these indicate that environmental pollutants have long-lasting, subtle effects on central nervous system function. As a result, experimentation on these specific neurophysiological and behavior effects of the heavy metals is continuing to ascertain the precise type of injury responsible for producing these effects. Both these general and specific methods can be applied to assess the neurotoxicity of any known or suspected toxicological agent or environmental pollutant.

Acute Lethal and *In Vitro* Toxicology of Metallic Sulfates

An estimate of median lethal doses (LD_{50}) of three metallic sulfates administered intravenously to female rats was determined (as mg element/kg body weight, calculated on basis of the chemical compounds shown):

Compound	*Estimated LD_{50}*
$PdSO_4$	1.1
$Pt(SO_4)_2 . 4H_2O$	2.2
$NiSO_4 . 6H_2O$	2.4

Deaths occurred in most cases immediately upon injection, and this pattern is consistent with the possibility of hemacoagulation phemomena occurring. The latter were shown to occur in *in vitro* experiments with rat blood at concentrations as low as 10 and 12 μg/ml blood for platinum and palladium, respectively.

Acute Lethal Toxicity and Protein Binding Properties of Palladium and Platinum Compounds

Lethality determinations of palladium and platinum chlorides using various routes of administration in rats and rabbits are presented in Table 4. Protein binding properties of palladium and platinum were found to be greater than 99% at all concentrations tested up to 200 μg/ml.

TABLE 4. LETHALITY OF PALLADIUM CHLORIDE COMPOUND IN RATS

Compound	Approx. LD_{50} mg/kg	LD_{50} mg/kg	Route
$PdCl_2$	5		IV
$PdCl_2$	70		IP
$PdCl_2$	200		PO
$PdCl_2$	6		IT
$PdCl_2$		3	IV
$PdCl_2$		123	IP
$\cdot K_2PdCl_4$		6.4	IV
$(NH_4)_2PdCl_4$		5.6	IV

Effects of Metal Sulfates on Succinate-Dependent Respiration *In Vitro*

The use of catalytic converters to control hydrocarbons and carbon monoxide in the automobile exhaust emissions resulted in an increased output of sulfate(s). This, along with possible emissions of noble metals (platinum and palladium) from the converter prompted us to test comparative toxicity of the various sulfates in an enzyme system. We tested the effects of various sulfates such as cadmium, palladium, manganese, magnesium, calcium, sodium, and ammonium on the system. The results indicate that the sulfate ion in tissue slices or in homogenate did not affect the respiratory chain. However, among the cations, cadmium ion appeared to be the most potent inhibitor (Figure 27). Cadmium ion, a known potent inhibitor of the mitochondrial respiratory chain was utilized in this experiment as a reference toxicant. Cadmium sulfate was found to be at least 5,000 times more toxic to the respiratory chain than palladium sulfate in this particular system. As expected, other cations such as cerium, manganese, magnesium, calcium, and sodium ions were not inhibitory at concentrations up to 10^{-3}M, but appear to have a slight stimulatory effect. Intragastric administration of a single dose of cadmium sulfate, platinum sulfate, and palladium sulfate at 0.08 M mole/kg body weight, did not affect succinate-dependent respiration in any of the organ tissues tested (kidney, liver, heart, and lung).

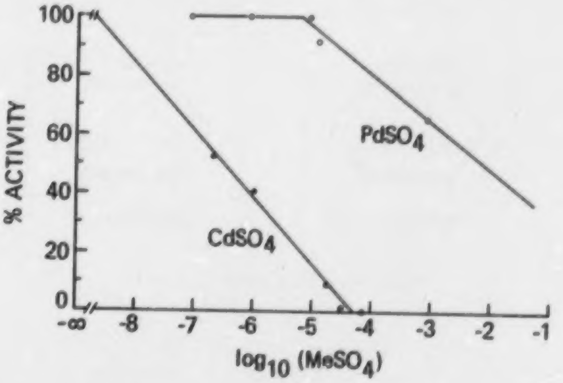


Figure 27. Effect of cadmium sulfate and palladium sulfate on succinate dependent oxygen-uptake in rat liver homogenate.

binding of heavy metal pollutants by polyuronic acids

Extracts of brown marine algae and pectates have been used in the past to prevent intestinal absorption of radiostrontium. Alginates and pectates are the only polyuronates known to occur in nature; alginate is present in brown seaweed and pectate is present in higher plants (Figure 28). The use of alginates as heavy metal binders *in vivo* has been studied by a number of workers and has been extended to metals other than radiostrontium, including cadmium and lead. Similar studies with pectates were initiated recently under a grant to Drs. S. Skoryna and Y. Tanaka (McGill University) and supplemented by in-house studies at ETRL.

Divalent metal ions (except magnesium) form an insoluble gel *in vitro* with polyuronates and, in this way, render the tested metal unabsorbable under *in vivo* conditions. Based on this premise, it appears that this type of ion-exchange reaction can be applied to control the excessive intake of trace elements in at least three situations: (1) at the source of release of the effluent from an industrial plant, (2) in cases of inadvertent pollution of water or food chains, and (3) after inhalation of toxic levels of metal particulate. The chemical process describing the *in vivo* action of polyuronates is shown in Figure 29, with mannuronate used as the example.

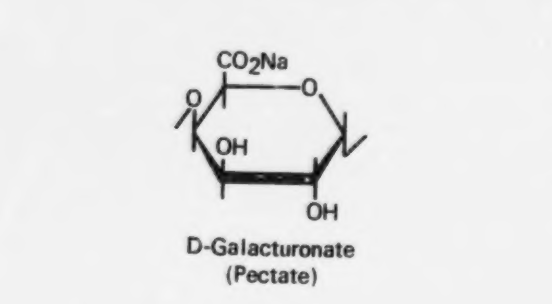


Figure 28. Chemical form of alginate and pectate.

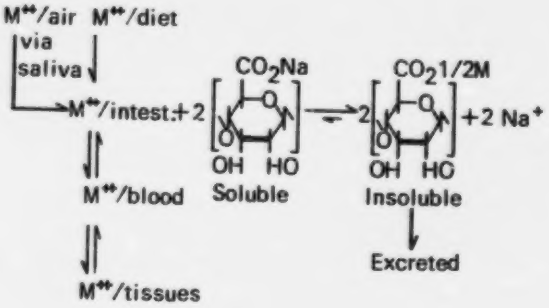


Figure 29. *In vivo* reaction of polyuronates.

IN VIVO AND *IN VITRO* BINDING EFFECTS OF POLYURONATES

Polyuronates have a potential use as a therapeutic agent because of the two-way transport process across the intestinal membrane. A nomenclature model for this process was proposed by C. F. Code* (Figure 30). He termed absorption to be the situation when the insorption fraction from the gut exceeds exsorption from the blood. Enterosorption is described as excess of exsorption over insorption.

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*C.F. Code, Persp. Biol. Med., 3:560, 1960.

Because of the "exsorption" process, the metals which enter the body via other routes other than oral may be partially removed by the binding process in the gut. Although the *in vitro* ion-exchange reactions of alginate with divalent metals have been studied in some detail, no comparable studies on pectates can be found in the literature. As a part of the ETRL program, both on contract and inhouse, the binding capacity of pectates was investigated to compare their metal-binding properties with alginates.

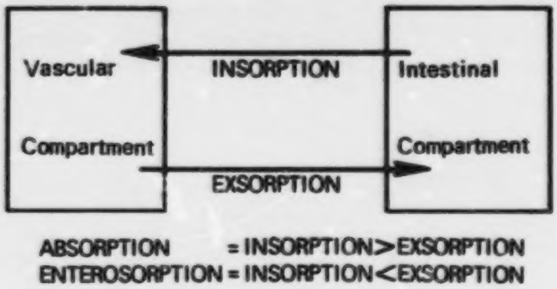

Vascular
Compartment
INSORPTION
EXSORPTION
Intestinal
Compartment
ABSORPTION = INSORPTION>EXSORPTION
ENTEROSORPTION = INSORPTION<EXSORPTION

Figure 30. Absorption and enterosorption process nomenclature. (Proposed by C. F. Code.)

Pectates were found to bind divalent metals *in vitro* in the following order:

Cd > Sr > Pb > Ni > Co > Zn > Mn > Ca > Cu > Ba

The positions of cadmium, strontium, and lead in the pectate series showed the most effective binding rate in comparison to the alginate series, which was as follows:

Pb > Cu > Cd > Ba > Sr > Ca > Co > Ni > Zn > Mn

Both compounds appeared to be quite effective for the three metals (Cd, Pb, Sr).

However, in the case of other metals, the differences observed between the alginate and pectate series were somewhat unexpected. For example, the pectate series showed a low binding capacity for copper when compared with the high binding capacity in the alginate series. Another significant difference is the position of calcium and barium.

The *in vivo* studies demonstrated that pectates are capable of reducing significantly the intestinal absorption of lead and cadmium. The results of modified pectate compounds on stable lead in ligated intestinal segments *in situ* are shown in Figure 31. The data showed that the removal of lead could be increased by increasing the ratio of sodium pectates to lead in the diet. If the ratio of sodium pectate to lead was 1:1, some 10-fold greater amount of lead was found to be bound in the lumen of intestinal segments as compared to controls; when the ratio was 3:1, the difference was almost 20-fold.

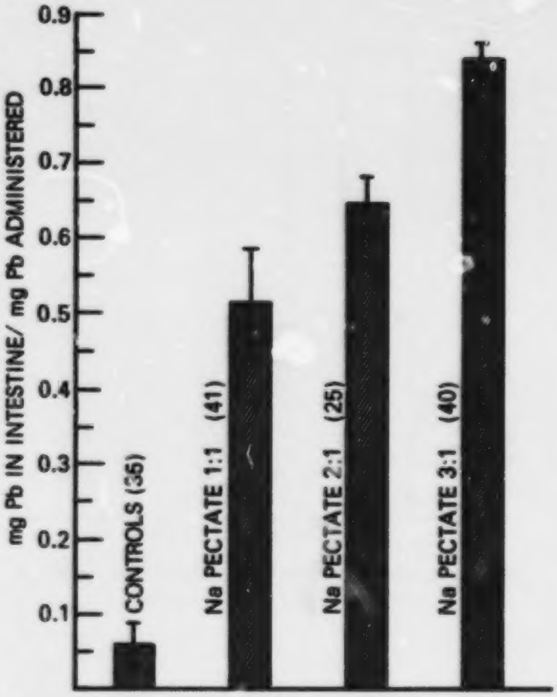


Figure 31. Effects of pectates on intestinal absorption of lead.

In another experiment, three groups of weanling rats were placed on a special diet to which 5 mg/kg of body weight of lead oxide (PbO) was added. One of the groups also received 10% polyuronate in the diet, another, similarly, 10% pectate. The result of analysis of variance of the mean values after 2 wk of feeding showed that the positive control group of animals had significantly higher mean blood lead levels than the other two treatments ($p > 0.0001$). No significant differences were shown between the two additives (Figure 32).

Following a lethal dose of cadmium to rats (80 mg/kg body weight), the mortality rate and renal cadmium content were altered following oral administration of alginates and pectates (Table 5). In both experiments, the mortality rates in animals fed the binding compounds were negligible when compared with the controls; the cadmium renal content was also much lower in the treated animals than in controls.

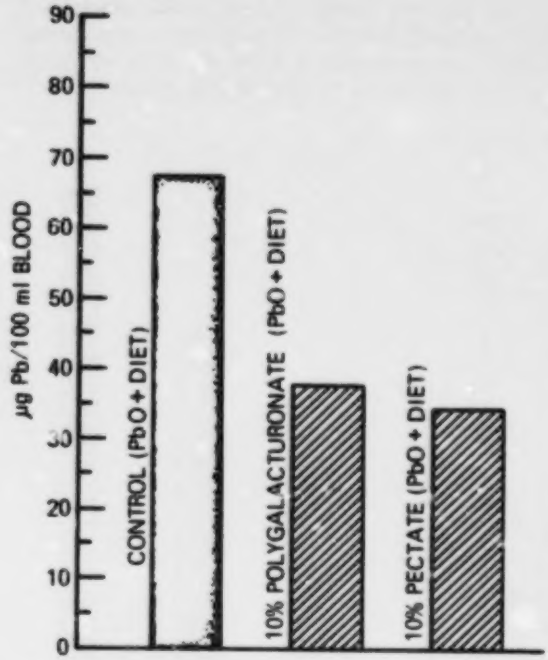


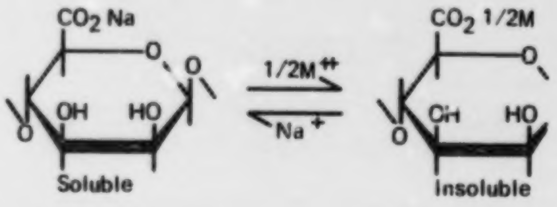
Figure 32. Effect of polyuronates and pectates on blood levels of lead in weanling rats.

TABLE 5. EFFECTS OF ALGINATE AND PECTATE ON MORTALITY RATE AND RENAL CONTENT OF CADMIUM

Test compound	Animal group	Mortality rate (%)	Renal content of cadmium (µg/g)
Sodium alginate	Experimental	7	5.8
	Control	85	9.8
Sodium pectate	Experimental	4	2.5
	Control	78	9.7

INDUSTRIAL APPLICATION OF POLYURONATES

In addition to their *in vivo* applications as metal binders in the intestinal tract, alginates and pectates may be considered for treatment of industrial wastes and recovery of trace metals, essentially by a simple ion-exchange process. (In this case natural polyuronates would have some advantage over synthetic resins, because of their specificity in the ion-exchange reactions.) Alginates and pectates form insoluble salts when they undergo ion-exchange reactions with heavy metals (M) (Figure 33). Thus, the reaction involves a change from homogenous to heterogenous phase. In this way, the heavy metal pollutants may be concentrated in the form of sediments; they, in turn, can be recovered from the sediments simply by reversing the equilibrium with alkali. While working on practical applications of polyuronates, the studies were extended to testing of polysaccharides containing half sulfate ester groups, which also have the capability of binding certain metals. It now appears that synthetic or semisynthetic (modified natural products) metal binders can be developed with high specificities for either *in vivo* or *in vitro* applications. The synthetic or semisynthetic metal binders may have even greater potential industrial application than the natural binders.



Change of Phase

(HOMOGENEOUS↔HETEROGENEOUS)

Figure 33. Ion exchange reactions of alginate.

ZONING THE BIOLOGICAL EFFECTS OF METALS

In addition to applying these compounds to industrial and preventive use, the research effort should be directed more towards determining how various levels of ingestion of these metals relate to their biological effects.

The literature does not have sufficient data on most metal pollutants to propose definite zoning of their biological effects with respect to species, age groups, particular systems or functions, and interactions with other metals at different levels. Figure 34 demonstrates, as an example, the classification of biological effects of cadmium and zinc in mature rats (in ppm × 10^{3}). The biological effect zones include deficiency level, physiological level, pharmacological level, toxicity zone, and lethal zone.

FOR THE FUTURE

Potentially this approach to zoning of biological effects of metal pollutants represents a suitable reference framework for investigations of health effects, monitoring, and application of control technology. Although presently such zone limits may have to be set arbitrarily because of the inadequate available data, the development for some approach to standardization of reporting on metal pollution of the environment and the related health effects is urgently needed.

With respect to the potential preventive aspects of the natural and synthetic binders, additional extensive *in vivo* experiments are needed to determine which of the polyuronate compounds are most specific for the binding of particular metals.

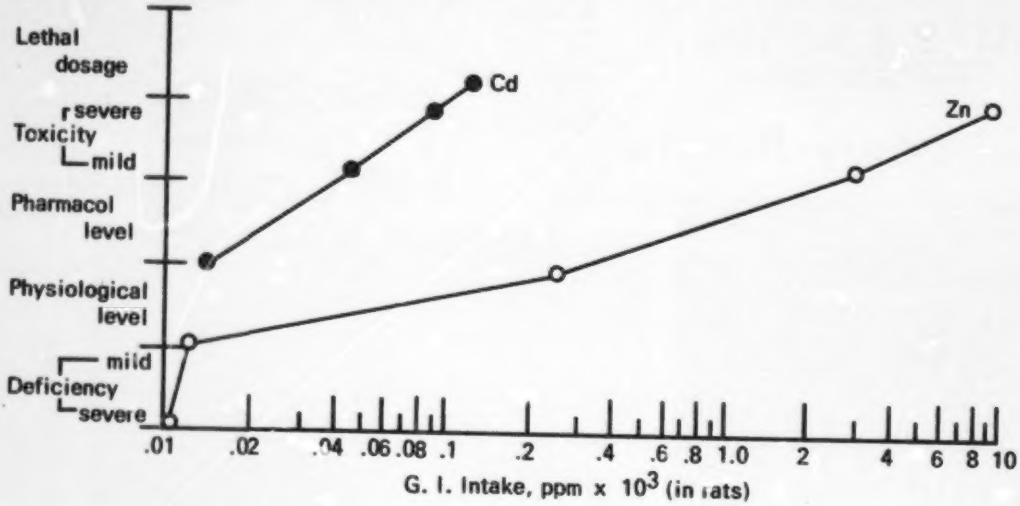


Figure 34. Zoning of biological effects of trace elements.

Slick Trick to Foil a Slic

Artificial Sea Used To Fight Oil Spills

The New York Times

DAILY NEWS

NEW YORK'S PICTURE NEWSPAPER

Shore Record

Monmouth County's Morning Daily

The Courier-News

The Daily Register

Spill prevention promised

The Star-Ledger

FINAL EDITION

Facility for oil spill cont

containment tests unvei

EPA testers wave goodby to Ma Nat

BUILD 'OCEAN' FOR OIL SPILL RESEARCH

Figure 35. (top left) Test underway at OHMSETT facility.
Figure 36. (top right) Foam plug for punctured containers.
Figure 37. (bottom left) Spray evaporator pilot plant for sulfuric acid recovery.
Figure 38. (center right) Reclaimed surface mine, Dents Run Watershed, West Virginia.
Figure 39. (entire page) OHMSETT dedication news coverage.

industrial waste treatment research laboratory

The Industrial Waste Treatment Research Laboratory (IWTRL, with staff and facilities in Edison and Leonardo, New Jersey; NERC Headquarters in Cincinnati; and Crown, West Virginia) is EPA's focal point for research concerning the identification, characterization, control and prevention of water pollution arising from the Nation's industrial operations. The program is devoted to demonstrating useful technology for the control of waste discharges from mining operations, the management of oil and hazardous material spills, and the reduction and treatment of industrial effluents.

INDUSTRIAL POLLUTION CONTROL BRANCH

Industrial pollution control efforts within NERC–Cincinnati are focused on the development and pilot and full-scale demonstration of technology for pollution abatement, including, where appropriate, process modifications resulting in maximum water reuse and byproduct recovery. The program includes nonferrous metals and metal finishing, plastics and rubber, cement, glass, inorganic chemicals, and a diverse group of chemical and related industries such as paints, drugs, photographic processing, etc. The expertise within the group continues to be used extensively for technical advice by other EPA activities such as Effluent Guidelines Division (Office for Water Planning and Standards) and Office of Solid Waste Management Programs in developing stringent but realistic standards. The industrial community benefits from the group's knowledge through publications and participation in Technology Transfer and other technical meetings. Several of the more significant projects directed toward the group's goals during 1974 are described below.

A pilot-plant system for the recovery of phosphoric acid from the aluminum-contaminated acid generated during bright finishing of aluminum has been developed and optimized. In the process, called "acid retardation," phosphoric acid but not aluminum is retained by strongly basic anion exchange resin. Regeneration of the resin requires water only, and the sludges inherent in conventional treatment processes are avoided. Cost, predicted to be significantly less than for alternative, conventional routes would allow full recovery of investment in 1½ yr. A full-scale demonstration project has now been initiated.

A new electrolytic process suitable for either dilute chromic acid or cyanide wastes has been evaluated on a full scale in an operating plating shop. A novel bed of carbon particles between electrodes overcomes the high power requirements usually required for the hydrolysis of dilute wastes. Although highly effective in removing hexavalent chromium (to < 0.05 ppm) from rinsewaters, the process is more sensitive to the nature of metal complexes present in cyanide wastes and, consequently, requires more complete evaluation before installation. Treatment chemical needs and sludge generation are drastically reduced compared with conventional reduction of hexavalent chromium or oxidation of cyanide and precipitation of metals.

The removal of copper from brass mill wastewaters by cementation with scrap iron has been evaluated on a bench scale and found to be very promising and highly economical. Copper removals of 99+% were achievable, and residual hexavalent chromium from pickling was totally eliminated (as Cr^{+6}). In addition, the copper is recoverable as a metallic flake, thereby reducing consumption of virgin ore and eliminating the need to dispose of copper sludges. Preliminary cost estimates indicate that the process could save $40,000 annually for a plant manufacturing 22,000 tons/yr of copper products. A full demonstration is anticipated in the near future to confirm the technical feasibility and economics.

A method has now been demonstrated by which a substantial increase in throughput or reduction in energy requirements or equipment size of vertical tube evaporators (VTE) can be achieved. Tests with a cooling water blowdown, a boiler blowdown, and an electroplating rinsewater have shown that the addition of low concentrations of certain surfactants to the wastewater increases VTE overall heat transfer coefficients approximately 100%, and causes a desirable reduction in pressure drop and a retardation of salt nucleation (Figure 40). Broad interest in the concept has led to a followup grant by the Utilities Industries Research Branch (NERC–Corvallis).

A pilot plant system for reclaiming the waste sulfuric acid generated during the manufacture of titanium dioxide pigment has been evaluated. Approximately 87% of the available acid was recoverable by a spray evaporation technique as 85% acid suitable for reuse in ore digestion. Extrapolation of the 2 tons/day pilot plant to commercial size (165 tons/day) gives an anticipated cost of $48/ton of reclaimed 100% acid, which is comparable to the cost of virgin acid PLUS those disposal costs expected in the near future. It should be noted, however, that the process is highly energy dependent and that no acceptable disposal or recovery route has yet been developed for the recovered metallic salts. (See color plate, Figure 37).

State-of-the-art surveys of the inorganic gases, commercial and military explosives, and plastics industries are nearing completion. These reports, documenting pollution sources and characteristics

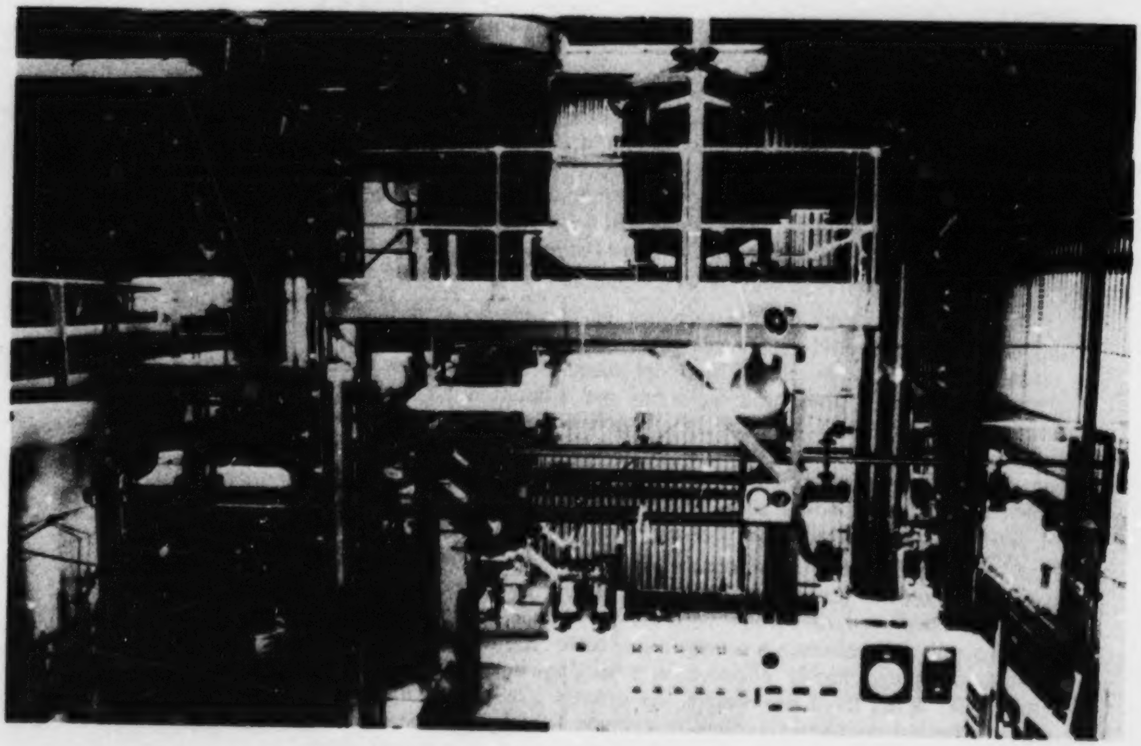


Figure 40. Modified foaming vertical tube evaporator.

and describing current water management and waste treatment processes, will be used in establishing the objectives of the program for pollution control research and development. In addition, they serve as valuable "pathfinder" studies for the development of industrial effluent standards.

HAZARDOUS MATERIALS SPILL RESEARCH

During 1974, the Hazardous Materials Spill Branch continued its broad-based program to develop equipment, techniques, and total systems for preventing, detecting and identifying, controlling, removing, and treating accidental discharges of diverse hazardous substances into the Nation's water environment. Such spills may react with water, float, emulsify, or sink and may be of immediate or long-term danger to man and his environment.

Typical of the activities of this branch was the use of the 1.3-l/sec (200-gpm) physical chemical treatment system developed under contract last year and used in the cleanup of creosote settled in the Little Menomonee River (Wisconsin). Subsequently, the unit was modified somewhat and placed on standby for use in other actual spill incidents. Within weeks, it was required for a herbicide (dinitrobutylphenol) spill in Clarksburg, New Jersey. During a 10-day period of continuous operation, the unit operated outstandingly and treated over 11,400 m^3 (3 million gal) of contaminated lake water. The DNBP concentration was reduced from 0.4 ppm to < 0.02 ppb, and the total cost of the operation was approximately $40,000.

The 2nd National Conference on the Control of Hazardous Material Spills, held in San Francisco, attracted almost twice as many papers as the 1972 Conference and was attended by over 600 persons representing the Federal, State, and municipal governments; industry; academia; and foreign countries.

Although technology exists for the proper design of earthen dikes used for storage of industrial wastes, improperly designed or constructed dikes fail with alarming frequency and often with disastrous consequences, such as at Buffalo Creek, West Virginia, in 1972. An acoustic-emission device has now been developed to assess the stability of such lagoon embankments (Figure 41). Metal rods inserted into the earthen dams pick up acoustical emissions caused by stress releases from interparticle (sand) and cohesive bond breaking (clay). The sounds are converted to a measurable electrical signal that can be associated with stress release and, thus, with dike stability during the filling or emptying of the lagoon. Marginally stable dikes almost constantly generate characteristic acoustical emissions, even at constant liquid levels. The system, simple and rugged in design, can be used to rate the integrity of dams both periodically in a preventive analysis program and when stress is applied (e.g., heavy rains). This technique, which has received a wide press and elicited over 200 inquiries, is being evaluated by the U.S. Department of Agriculture at earthen dams in Nebraska and Pennsylvania and by Bethlehem Steel Company on iron ore storage piles at Sparrows Point, Maryland.

Figure 41. Acoustic sensing system for dam stability.

As part of a model contingency plan, preventive measures are being assessed in a 115-m^3/day (30,000-gpd) pilot plant to prevent spilled hazardous materials and industrial wastes from entering the interceptor system of a municipal secondary sewage treatment plant. The pilot plant closely models the 570,000-m^3/day (150-mgd) municipal plant where the concepts would be applied.

Transfer-line ruptures and tank overfilling have been identified as major sources of hazardous material spills. Contracts are now underway to develop practical, low-cost systems to automatically shut down transfer operations in an aniline plant if ruptures or severe leaks occur and to test improved fluid-level gauges in various organic chemical facilities.

The quantities of absorbent required and efficiency of pickup of both freefloating and "tea-bag"-contained mass-transfer media (activated carbon) are being evaluated in a flowing but captive stream (Figure 42). The model stream was created by

Figure 42. Captive stream for hazardous spill testing.

modifying an abandoned mile-long drainage canal at the AEC's Hanford site. A sluice gate allows artificially contaminated water stored in the upper 460 m (1,500 ft) of the canal (PVC-lined) to enter a 760-m (2,500 ft) channel, which serves as the testing stream. After experimental treatment, the water is collected in a large PVC-lined sump at the end of the channel for further treatment, as necessary, before discharge.

The 16-l/sec (250-gpm) trailer-mounted dynamic reactor (Dynactor)/magnetic separator, complete with high-rate clarifiers, is approximately 50% complete. In operation, the unit will convert contaminated wastewater to a fine mist that rapidly "reacts" with powdered carbon. The loaded carbon is then removed and the treated water discharged.

A pallet-mounted, battery-operated pump and a furled 26.5-m^3 (7,000-gal) plastic collection bag system has been developed and demonstrated for the collection and temporary storage of spilled hazardous liquids. The complete package, including 30 m (100 ft) of heavy duty suction hose stands about 0.9 m (3 ft) high on a 1.2-m by 1.2-m base (3 x 4 x 4 ft), weighs about 450 kg (1,000 lb) and is easily transportable in a pickup truck (Figure 43). An improved version, which will include an explosion-proof diesel generator, a collection bag of superior chemical resistance, and an improved method for transferring the fluid from the bag to another container, is now being fabricated for evaluation in conjunction with the backpack foam-generation system developed under an earlier contract for diking spilled hazardous substances.

Figure 43. Portable spill containment system.

A contract has been awarded for optimizing the formulation of a universal gelling agent and for developing a flexible dispensing system capable of applying one or more of the five component gelling agents, depending on the nature of the spill. Thus, the system will be applicable to situations where the spilled material is unidentified as well as those where its nature has been established.

Major improvements have been made in the one-man-operable, foamed-in-place plastic plug for controlling leaks from punctured containers. In the modified system the urethane foam is injected into an open-pore sponge enclosed in a tear-resistant rubber envelope. The envelope is forced partially through the rupture into the container to form a seal on both sides of the rupture and to add structural rigidity to the plug. (See color plate, Figure 36.)

Through an interagency agreement with Edgewood Arsenal, an off-the-shelf, hand-carried kit is being adapted for locating and tracking spill plumes in watercourses. A movable, instream spill sensor and warning system is also being developed under contract to aid in cleanup operations in the field.

MINING POLLUTION CONTROL

Current energy difficulties are an added impetus for developing and demonstrating improved technology to prevent and abate water pollution caused by increasing mineral extraction and mining (coal) activities and for assessing environmentally sound mining methods for new mines. Efforts within this program are directed toward problems of acid mine drainage, sediment-bearing runoff, and spoil stabilization from active and abandoned surface and underground coal mines; unidentified problems of the oil shale and geothermal energy industries that may be about to develop; and the water pollution from uranium mining and processing.

The reclamation of 41 ha (102 acres) of surface mines in the Dents Run Watershed near Morgantown, West Virginia, was completed. (See color plate, Figure 38.) Before this demonstration project, these mines were catching runoff water and directing it into an underground mine where the water then flushed out acid mine drainage. The post-demonstration monitoring of the reclamation site, scheduled to be completed in 1975, is expected to show the reduction and eventual elimination of the acid discharges resulting from reduction of the inflow. Several other reclamation projects, each with its own unique problems, are also underway in cooperation with several different State agencies.

The Crown Field Site pilot plant in West Virginia is now complete and in operation. Studies are underway on the treatment of acid mine drainage by reverse osmosis, ion exchange, and neutralization with lime and limestone. In addition, a lagoon, sludge drying beds, and a spray irrigation system are available and are being used to evaluate methods for disposing of treatment process wastes.

Laboratory and field studies have been conducted to determine the technical feasibility and economics of removing ferrous iron from acid mine drainage by an electrolytic oxidation process (Figure 44). A bed of conductive particles is employed between the cathode and the anode of the cell to increase electrical conductivity. Although approximately 86% of the iron could be converted to the ferric state, the process was found to be more costly than conventional aeration schemes.

Ozone and hypochlorite were evaluated in the laboratory for the removal of manganese from acid mine drainage. Although both agents effectively oxidized manganese to manganese dioxide, which precipitated, cost analysis indicated that the hypochlorite would probably be more economical for low manganese concentrations and low flows and that ozone was more economical at the higher concentrations and flows.

Bulkhead seals are considered one of the most promising methods for controlling acid mine drainage discharges from abandoned underground mines.

The seal in the mine opening causes the mine to flood, thereby excluding air and preventing further production of acid. The major drawback to date has been the cost of the seal. In an attempt to reduce the cost, a self-sealing limestone seal is under investigation. Fine limestone is placed in the mine opening; as the acid mine drainage flows through the limestone, it is neutralized to form calcium sulfate and iron hydroxide, which plug the interstitial gaps. Based on a laboratory study that defined limestone particle size, type, and density for optimum

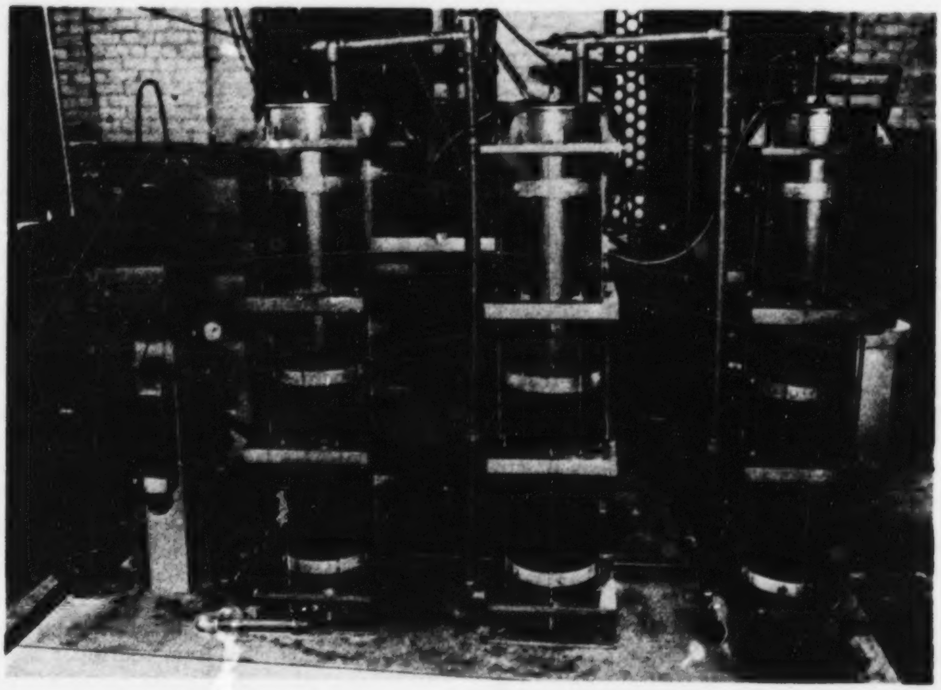


Figure 44. Electrochemical treatment of acid mine drainage.

seal strength, three seals are now being constructed at an abandoned mine for field evaluation.

A comprehensive review of the status of surface coal mining in both eastern and western United States, "Surface Mining of Coal," has been prepared. The damage to land and waterways caused by surface mining and techniques that can help to minimize these adverse effects, including revegetation and reclamation, are discussed. Areas requiring further research and development are also highlighted.

OIL SPILL CONTROL TECHNOLOGY

Activity in the area of oil spills is directed toward the detection and identification, containment, and removal of oil and related petroleum products accidentally discharged to inland and coastal waterways. The EPA must play a major role in developing the technology and hardware to combat increasingly frequent environmental insults from accidental spills during the production and transportation of petroleum products as the Nation's energy needs expand over the coming years.

At Leonardo, New Jersey, the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT), a $3 million facility for developing and modifying, testing, and evaluating spill cleanup methods and equipment, has now been transferred from the construction contractor to the IWTRL. (See color plate, Figure 39.) This tank (200 m long, 20 m wide, and 3.4 m deep; 670 x 65 x 11 ft) can simulate various inland and protected fresh or estuarine water environments such as those in which a large portion of all spills occur. Waves up to 0.6 m (2 ft) high and 15 m (50 ft) long can be generated, and full-scale test equipment can be towed at speeds corresponding to currents up to 6 knots. An adjacent quality control laboratory, occupying 93 m^2 (1,000 ft^2), will furnish all necessary support service. (See color plate, Figure 35.)

Careful design has resulted in an environmentally safe facility incorporating blind sumps for drainage, an overflow weir, equalization tanks, a coalescer, and a diatomaceous earth filter to ensure that the water discharged will meet all State and Federal standards.

Although intended primarily for in-house use in developing technology for oil and hazardous material spill control, the unparalleled facilities of OHMSETT will also be used by other agencies such as the U.S. Coast Guard and the Navy to evaluate commercial and prototype equipment for their needs. Rental funds from these and other users will help defray EPA operating cost.

Development of containment devices capable of operating in water having velocities greater than 2.5 knots continues to be a high-priority activity. A streamlined, air-foil-shaped boom capable of recovering 65% of the oil encountered in a water body flowing at 3 knots is presently being evaluated. The contractor is carrying out water channel studies in order to modify the boom profile so that collection efficiency at 3 knots can be improved. A full-scale unit will subsequently be fabricated and tested at OHMSETT.

The Dynamic Inclined Plane (DIP) skimmer concept developed under contract for the Oil Spill Branch by JBF Scientific Corporation (JBF 4001) has now been adapted to and successfully tested in the open sea under an American Petroleum Institute contract. Although EPA no longer finances this work, our interest continues because the skimmer culminates a successful concept development sponsored by this Laboratory.

A perforated, inclined plate boom developed by the Shell Oil Company is being evaluated at OHMSETT (Figure 45). The device has demonstrated a collection efficiency of 85% with a 2-mm slick of No. 2 fuel oil at a simulated current of 2.9 knots. Conventional booms would be able to contain only approximately 50% of the oil under comparable conditions and would exhibit severe deterioration in efficiency as the current increases.

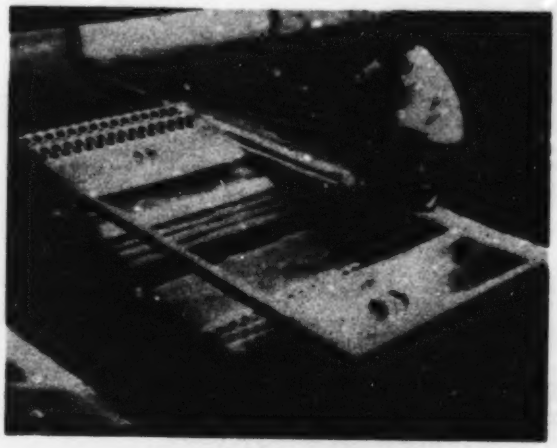


Figure 45. Inclined plate oil spill boom.

The capability for removing isolated oil must keep pace with containment technology. To date, these efforts have been restricted to the shoreline and piers where necessary land-based support was available. A high-speed skimmer capable of operating independently in open water is now being developed under contract. In this unit, a direct air jet separates and lifts the oil slick from the water as a fine oil/water mist that impinges on a continuous polyurethane foam collection belt where oil is preferentially absorbed. The foam belt is then squeezed to remove the entrained oil and residual water. In tests that employed IWTRL's 30-m-long (100-ft) indoor tank, a prototype unit exhibited an oil removal efficiency of 65% on a single pass. Upon completion of the prototype testing, the unit will be modified as necessary and subjected to more severe and more realistic testing at the OHMSETT facility.

A high-speed, thin-film recovery device using an "air sweep" principle is also under evaluation. With this concept, an air blast is directed at the water surface to create a surface current in the water that can be controlled to move oil film into thickened "ribbons" or windrows. Tests in IWTRL's 30-m (100-ft) indoor test tank have shown the prototype unit capable of removing 75% to 80% of the oil encountered as a 1-mm slick while moving at a speed of 4 knots. Tests are planned at OHMSETT to develop and modify the device to its design potential of 6 knots. The U.S. Coast Guard has contracted to develop a Seagoing Skimmer using the same "air sweep" principle.

Part of the problem of preventing and controlling oil spills lies in detecting and identifying spills so that sources may be isolated and, where necessary, appropriate enforcement action initiated. The oil spill control program has been actively seeking new methods for characterizing aged oil and quantitating oil in fresh and saline water. An infrared spectophotometric method has been developed inhouse for the quantitative determination of low concentrations of oil dispersed in water. This method, which uses a Freon or carbon tetrachloride as the extractant, is accurate to the 50-ppb range that might be experienced in brine discharges from an off-shore oil producing platform. The procedure has been submitted to the Methods Development and Quality Assurance Laboratory for inclusion in the EPA Methods Manual.

Off-shore oil production can be expected to grow rapidly as the United States strives for energy independence. A major technical assistance program was undertaken by the staff of the Oil Spill Control Branch for the Division of Oil and Special Materials, Region VI, and Region X. The group's expert assistance, including field trips to some 30 operating drilling rigs off the coast of California, Alaska, and in the Gulf of Mexico, has been invaluable in assessing the proper design and operation of exemplary oil/water separation facilities and in identifying the causes and potential effects of disruptions in normal operation. Members of the Branch will continue to advise Regions VI and X until final permits on such off-shore oil platforms have been issued.

In a recently completed contract study of waste oil volumes and sources, recycle methods, and their environmental impact, it was estimated that 9.5 million m^3 (2.6 billion gal) of waste oil are generated annually in the United States. Only a relatively small quantity is re-refined and reused as lubricating oil. Most finds its way into the environment through its use in road oiling, in dust control, or as a fuel, or it is disposed of to landfills and dumps. Disposal of oily sludges from wastewater treatment is a major industrial problem. These methods endanger our environment; oil leaches to surrounding land and waterbodies or contaminates the air with lead when burned as a fuel. The report recommends development of a technically and environmentally acceptable oil recycling industry and expresses the opinion that the commonly used acid clay re-refining process cannot meet this need because of cost and its own unacceptable waste products. A study for EPA by Maryland's Environmental Service similarly recommended an expanded waste oil reclamation program and estimated that costs would vary from $3 million for plants treating 28,000 m^3/yr (7.3 million gal/yr) to $7.5 million for those treating 114,000 m^3/yr (30 million gal/yr).

Personnel in IWTRL's oil spill program contributed major sections on the generation of waste oil, re-refining technology, collection, disposal, and reuse as fuel to the report to Congress entitled "Waste Oil Study," which was required under Section 104(m) of the Water Pollution Control Act of 1972 (PL 92-500).

use of coal mine refuse and fly ash as a road base material

Two coal-related waste products, fly ash and coal mine refuse, were tested as road base material at the Agency's Crown Mine Drainage Control Field Site near Morgantown, West Virginia.

The emphasis of the study was to determine the suitability of these two waste products as a useful road base material in lieu of their being an environmental detriment. In addition, an evaluation was made to determine if water percolating through the base material would leach undesirable material and become a pollution problem. The refuse consists largely of shale, pyritic material, and some coal, all of which are removed from the raw coal during the washing process. The fly ash is the waste product from coal-fired power plants.

DESIGN OF TEST

In the road base material, the coal mine refuse (CMR) served as the load-bearing aggregate. Fly ash (FA) was used to fill the voids between the refuse to increase stability and, because of its alkaline nature, to neutralize any acidity produced from the pyritic refuse material. Lime was added to assure alkaline conditions and to reduce porosity.

The construction area (Figure 46) was divided into three segments to investigate different base-course mixtures. Area 1, covering 86 m^2 (920 yd^2), was the largest of the three and, as the main entrance and parking area, was subject to the heaviest traffic. The base course for Area 1 (Figure 47) was composed of a 30.5-cm-deep (12-in) mixture of 75% CMR and 25% FA. The materials were mixed with an end-loader before placement and placed in two 15-cm (6-in) lifts. A three-wheeled steel roller compacted the mixture.

Area 2, with an area of 21 m^2 (220 yd^2) was smaller than Area 1 and subject to less traffic. The base was placed in two lifts (Figure 48). The first 15.2-cm (6-in) lift was the same mixture used in Area 1 (75% CMR and 25% FA). For the top 15.2-cm (6-in) lift, 5% of lime (by weight) was mixed with the CMR-FA mixture by repeated passes with a road grader (Figure 47). The lime addition was made to offset possible acid production of the refuse. Weight calculations were based on CMR-FA density measured during construction. Typical density values were around 1920 kg/m^3 (120 lb/ft^3). At 5% by weight, the lime requirement for Area 2 was approximately 2720 kg (6000 lb). Adequate inplace mixing of the lime with the CMR-FA mixture was difficult because the lime flowed like water in front of the grader blade. Mixing the constituents before placement of the base would avoid the problem.

Area 3 was the same size as Area 2 but was subject to the least traffic. The base course for Area 3 consisted solely of 38.1 cm (15 in) of coal mine refuse placed in two lifts (Figure 47).

All three areas received the same surface treatment based on West Virginia Department of Highways (DOH) recommendations. A two-wheeled steel roller compacted 7.6 cm (3 in) of base course asphalt with a 2.5-cm (1-in) wearing course of asphalt (Figures 49 and 50).

COST

The fly ash and refuse were provided to the contractor at no charge; thus, the only expense to the contractor was transportation from the source to the site. The cost of each treated area was not determined. Average cost of the pavement was \$10.92 m^2 (\$9.13/yd^2).

SAMPLE COLLECTING

A drainage monitoring system was installed between the base course and the subgrade (Figure 51). The drainage monitors were 6.4-m (21-ft) joints of 3.8-cm (1½-in) perforated PVC pipe laid

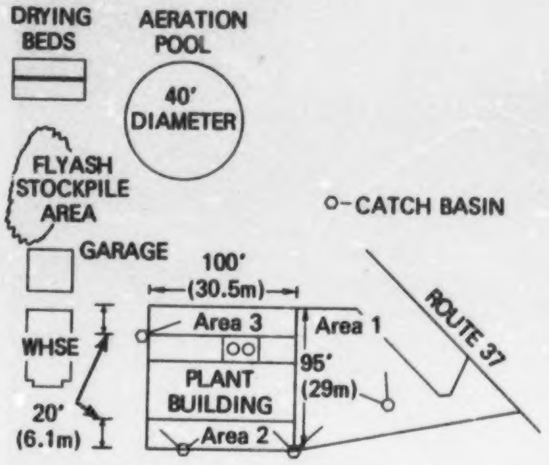

DRYING BEDS
AERATION POOL
40' DIAMETER
FLYASH STOCKPILE AREA
O- CATCH BASIN
GARAGE
100' (30.5m)
Area 3
Area 1
ROUTE 37
WHSE
95' (29m)
PLANT BUILDING
20' (6.1m)
Area 2

Figure 46. Crown Field Site — road base study.

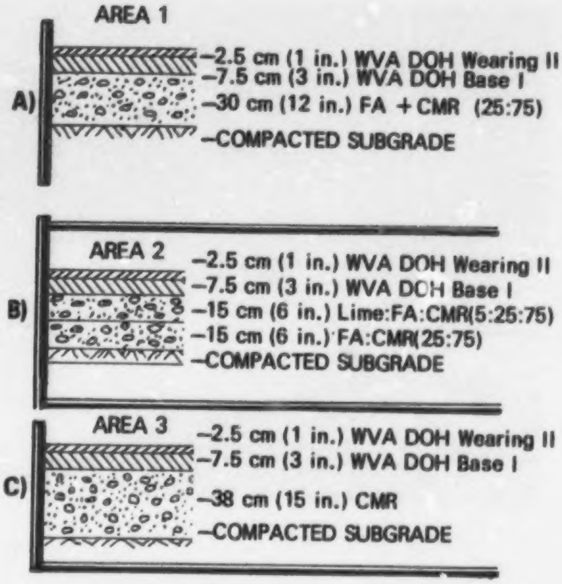
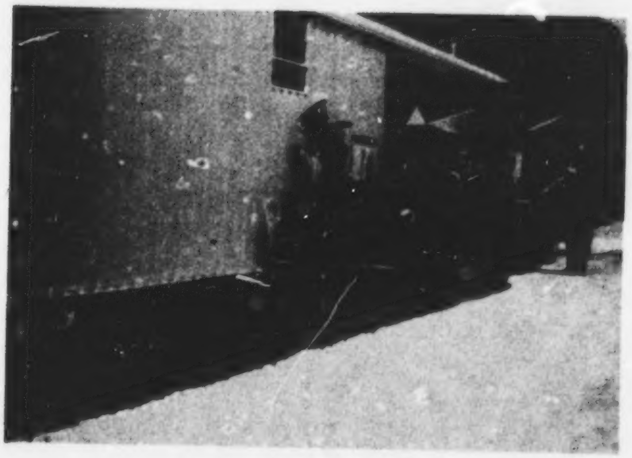

AREA 1
A)
-2.5 cm (1 in.) WVA DOH Wearing II
-7.5 cm (3 in.) WVA DOH Base I
-30 cm (12 in.) FA + CMR (25:75)
-COMPACTED SUBGRADE
AREA 2
B)
-2.5 cm (1 in.) WVA DOH Wearing II
-7.5 cm (3 in.) WVA DOH Base I
-15 cm (6 in.) Lime:FA:CMR(5:25:75)
-15 cm (6 in.) FA:CMR(25:75)
-COMPACTED SUBGRADE
AREA 3
C)
-2.5 cm (1 in.) WVA DOH Wearing II
-7.5 cm (3 in.) WVA DOH Base I
-38 cm (15 in.) CMR
-COMPACTED SUBGRADE

Figure 47. Cross sections of experimental road bases.

Figure 48. Placing the CMR-FA material (Area 2).

Figure 49. Blacktopping compacted base (Area 2).



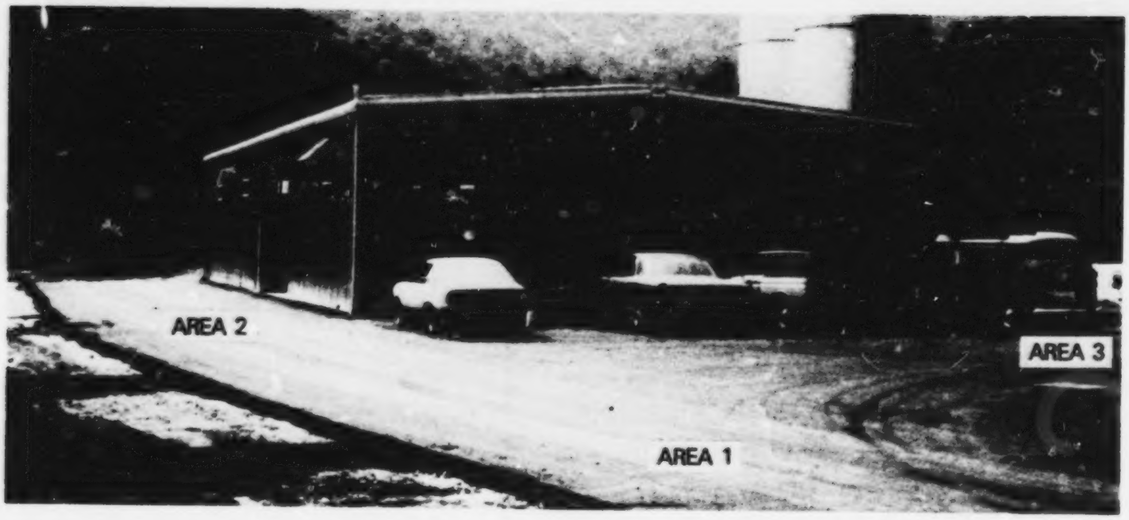


Figure 50. Finished project area.

on 6-mil polyethlene plastic sheeting. The base course was carefully placed over the pipes. Discharges from the pipes drained into catch basins and were collected in plastic containers (Figure 52). Samples were generally collected on a weekly basis during the early part of the study. No problems were encountered with excessive volumes of leachate during heavy rains.

RESULTS AFTER 1 YEAR

Field compaction of the base materials was satisfactory; the density of the inplace materials exceeded the laboratory design values.

The quality of the effluents from Areas 1 and 2 seems inoffensive at present. The effluents are characteristically neutral or slightly alkaline and have minimal concentrations of aluminum, boron, iron, and sulfate.

The quality of the effluents from Area 3, where the base material is entirely coal mine refuse, has deteriorated. The pH value of the effluent has dropped from 7 to near 3, and acidity has increased to over 3000 mg/l (Figure 53). The aluminum, iron, boron, and sulfate concentrations are rapidly increasing (Figure 54).

CONCLUSIONS

The leachate from the mixtures of refuse and fly ash and of refuse and fly ash plus lime did not constitute an environmental problem during the first 10 mo following construction. Monitoring will be continued over the next few years to determine if this trend continues.

The coal refuse material alone produced an undesirable discharge and, based upon this study, would not be an environmentally acceptable road base.

After 10 mo, the structural characteristics of the base materials were satisfactory for use in specific situations where its applicability must be determined on an individual-case basis (e.g., such factors as design loading, traffic characteristics, drainage, frost effects, etc., must be considered).

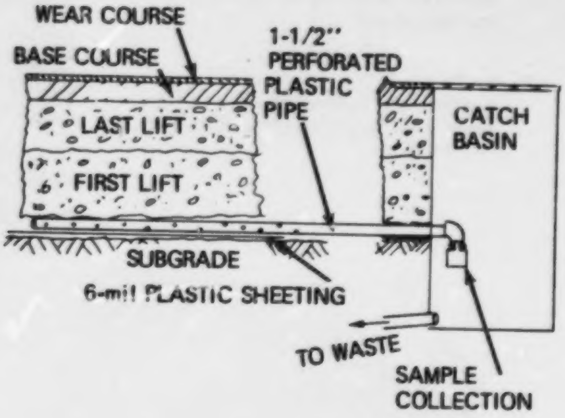

WEAR COURSE
BASE COURSE
1-1/2"
PERFORATED
PLASTIC
PIPE
LAST LIFT
FIRST LIFT
CATCH
BASIN
SUBGRADE
6-mil PLASTIC SHEETING
TO WASTE
SAMPLE
COLLECTION

Figure 52. Drainage monitoring system.

Figure 51. Placement of drainage monitoring system.

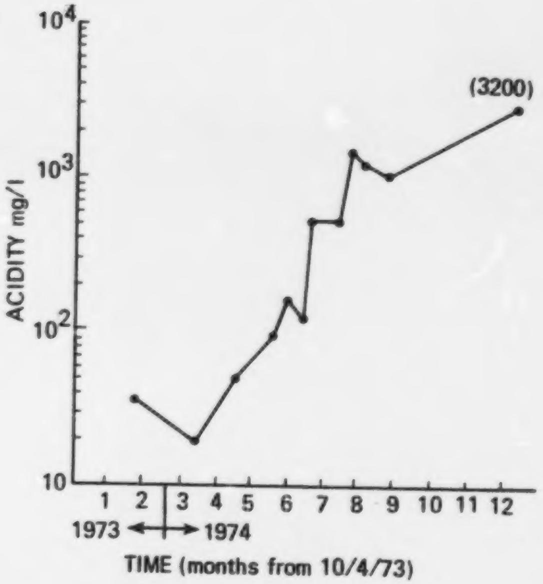


Figure 53. Acidity in Area 3 leachate.

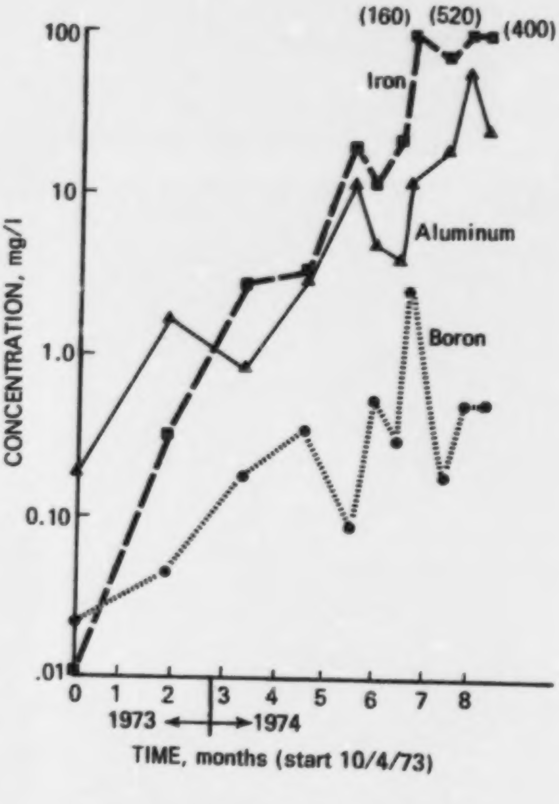


Figure 54. Pollutant trends in Area 3 leachate.

Figure 55.

(top right) Sampling for salmonella in the Ohio River.

Figure 56.

(center left) Collection of sediments to be used for preparing quality control samples.

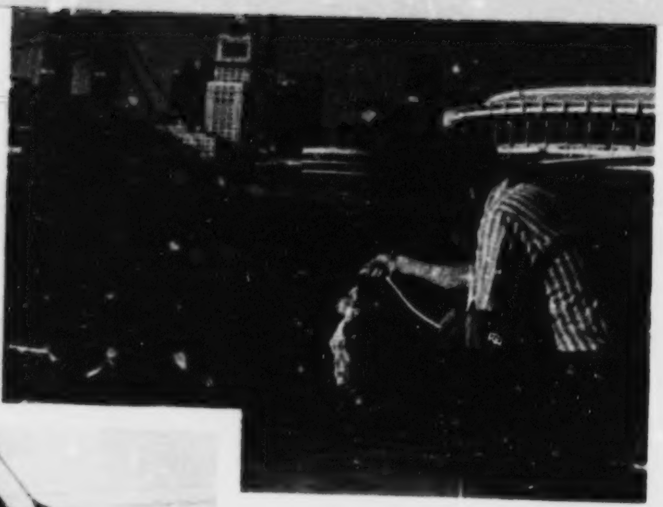
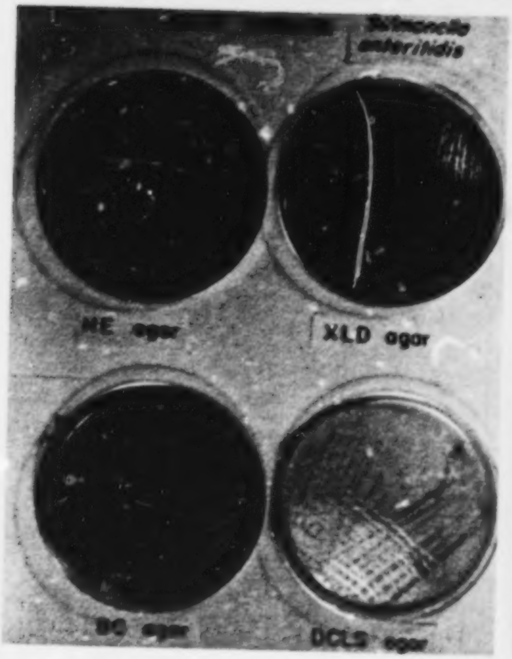


Figure 57.

(bottom left) Selective plating media for salmonella recovery.

Figure 58.

(bottom right) Performing membrane filter tests on chlorinated effluents.


Salmonella enteritidis
HE agar
XLD agar
BG agar
DCLS agar

methods development & quality assurance research laboratory

The activities of the Methods Development and Quality Assurance Research Laboratory (MDQARL) are concerned with selecting, developing, and evaluating methods for the analysis of water and wastewaters, and with developing quality assurance systems for laboratory control. The research includes physical, chemical, biological methods involving viruses, bacteria, algae, and aquatic macroinvertebrates and radiological and instrumental monitoring. Quality assurance aspects and the evaluation of laboratory performance are an important part of the activity.

Methods are published and made available to all EPA laboratories, States, universities, industries, and private laboratories reporting water and waste data for the National Pollution Discharge Elimination System (NPDES). Standard methodology is provided for monitoring systems, contract and grant projects, and enforcement actions. Coordination and participation in methods selection in the private sector is practiced through committee representations with organizations publishing *Standard Methods for the Examination of Water and Wastewaters* (Standard Methods) and *American Society for Testing Materials Methods* (ASTM). As a result, duplication is eliminated and methodology adopted is more uniform.

Quality assurance begins with the selection of the method. Methods are validated through interlaboratory studies. The laboratory supplies reference samples for analyses to test performance and provides quality control guidelines for laboratory operations. Systems for evaluating water and waste laboratories are developed through grants and contracts.

PHYSICAL AND CHEMICAL METHODS DEVELOPMENT

The physics and chemistry studies of MDQARL are subdivided into three functional areas, each with specific assignments for analytical methods development in a particular area of expertise: general inorganic analyses including trace metals; organic analyses such as pesticides, oil identification, and other trace organics; and advanced instrumentation.

Inorganic Analyses

Compliance monitoring of point-source discharges, as required by NPDES, has accelerated the need for simple, reliable pollutant-detection methods that can be used for all types of water and waste systems at the part-per-billion level. Studies have been completed on such a method for nitrates. Essentially, a filtered sample is passed through a column containing granulated copper-cadmium to reduce nitrate to nitrite. The nitrite (originally present plus reduced nitrate) is determined by diazotizing with sulfanilamide and coupling with N-(1-naphthyl)-ethylenediamine dihydrochloride to form a highly colored azo dye, which is measured spectrophotometrically. Separate, rather than combined, nitrate-nitrite values are readily obtained by carrying out the procedure first with, and then without, the initial copper-cadmium reduction step. Interference from metals is eliminated with the use of disodium ethylenediamine tetraacetate; oil and grease are removed by acid extraction with Freon. The sensitivity of the method is 0.01 mg NO_3-N/l with a working range of 0.01 to 1.0 mg N/l.

Studies to improve the analytical methods for determining cyanide and compounds of cyanide were another area of concentration in 1974. An improved method for total cyanide and a new method for cyanides amenable to chlorination were prepared for EPA's 1974 edition of *Manual of Methods for Chemical Analysis of Water and Wastes.* A third procedure utilizing a cyanide-selective ion electrode was prepared for use in a method evaluation study and for possible approval as an optional method for determining total cyanide after distillation.

ASTM methods for determining bromide, iodide, and sulfite have been evaluated using a variety of waste effluents. Interferences have been identified and modifications made to improve the procedures. Single-operator precision and accuracy have been obtained.

In the area of trace metal analyses, single-operator precision and accuracy data were obtained for beryllium, thallium, antimony, nickel, cobalt, molybdenum, tin, vanadium, titanium, and barium in a mixed domestic/industrial effluent using conventional atomic absorption (AA) techniques. These data are included in the *Manual of Methods for Chemical Analysis of Water and Wastes.* Investigations on the use of the heated graphite atomizer (HGA) in conjunction with AA analyses are continuing. The system is capable of measuring total concentrations of a variety of metals at extremely low levels with little or no sample pretreatment. Using a programmed sequence, a liquid sample is dried, charred, and subsequently atomized.

Because of the difficulties of measuring selenium with the use of other analytical techniques, a method using the HGA has been developed and is currently being evaluated on a variety of industrial wastes, domestic/industrial effluents, sludges, sediments, and surface and well waters. The selenium is solubilized by a nitric acid — hydrogen peroxide digestion. Nickel nitrate is added and a representative aliquot is pipetted into the furnace for complete ashing and formation of nickel selenide, a stable compound, which allows the use of a high charring temperature (1500°C) for the removal of many interferring substances. Preliminary data using this technique suggest that a detection limit of 1 μg selenium/l in tap water is easily achieved. With the use of method of standard additions, the apparent detection limit in industrial effluents is 5 μg/l. The full applicability of this method will not be known until the current evaluation has been completed.

Organic Analyses

To meet the Agency's needs for analytical methods to detect and quantify toxic and hazardous organic compounds in industrial effluents, receiving waters, and the water-related environment, a continuing program for development and application of new methods and the updating of existing methods is maintained by our Organic Analyses Section. Investigation of methods for quantification of oil and grease and for characterization of petroleum oils continued.

Volatile Organic Compounds

Development of a new method for isolation and determination of volatile organic compounds has been completed and is the subject of a NERC–Cincinnati report. Compounds that are relatively insoluble in water are purged from the sample by an inert gas. The volatile organics are quantitatively transferred to the gaseous phase and adsorbed onto an inert trap. The trap is then inserted into a gas chromatograph and the adsorbed organics are eluted and determined by programmed temperature gas chromatography. The sensitivity of the method using 5 ml of sample is 0.5 μg/l for many compounds. The sensitivity can be improved by scaling up the sample size and trapping system. The method is useful over a concentration range of 0.5 to 2500 μg/l.

Some specific compounds detected in water and wastewater using this technique are: methylene chloride, ethyl alcohol, chloroform, bromodichloromethane, dibromochloromethane, carbon disulfide, 1,1,1-trichloroethane, 1,1,2-trichloroethylene, 1,1,2,2-tetrachloroethylene, dichlorobenzene, and trichlorobenzene. The identity of all these compounds was verified by gas chromatography — mass spectrometry (GC/MS).

Vinyl Chloride

The purging and trapping technique described above has been applied to the determination of vinyl chloride in water. With the use of proper sample collection and standard preparation techniques, quantitative determination of vinyl chloride is possible. The method is being prepared for publication.

Benzidine

Several methods for the determination of benzidine and its salts have been evaluated. The chloramine-T oxidation method, modified to provide improved selectivity sensitivity, is now recommended for the determination of benzidine. The detection limit is

0.2 μg/l when analyzing a 1-liter sample. The coefficient of variation at 1.8 μg/l is 5%.

Oil and Grease

Evaluation, modification, and selection of methods for quantifying oil and grease in water and industrial and municipal effluents were completed last year. During the current year, the methods were written up and incorporated into the 1974 edition of *Manual of Methods for Chemical Analysis of Water and Wastes*. Interlaboratory studies of the methods are planned.

Characterization of Oils

The electron capture detector gas chromatographic (ECGC) method has been used to identify No. 2 fuel oil. Highly specific "fingerprints" obtained by ECGC when applied to the derivatized organic minor components (24 peaks) of spilled No. 2 fuel oil matched those obtained from the No. 2 fuel oil found at the source. This confirmed the identification made by infrared spectrophotometry and flame ionization gas chromatography.

Direct gas chromatographic analysis of a sample from a diesel fuel tank confirmed that it has been contaminated with gasoline. By comparing selected gas chromatographic peaks of the suspected gasoline, the top layer sample from the fuel tank, and the bottom layer sample from the fuel tank, it was possible to quantitatively determine the amount of gasoline in the diesel fuel.

Thiophosphate Pesticides

Recoveries for nine thiophosphate pesticides ranged from 95% to 103% at the 500 ng/l level and 96% to 103% at the 1000 ng/l level. The respective standard deviations varied from 12 to 27 and 5 to 46. The current method for recovering these pesticides was found to be unsuitable for Naled, TEPP, and Phospharnidon. Methods development is continuing for these compounds and for dichlorvos, dimethoate, and Azodrin.

Toxaphene

Precision data were obtained on environmentally contaminated industrial effluent samples. The average recovery was 32.2 μg/l with a standard deviation of 0.7. The percent recovery from the same samples dosed with an amount equivalent to the average recovery from the original samples was 82%.

Polychlorinated Biphenyls

Accuracy and precision data were obtained on environmentally contaminated industrial effluent and lake bottom samples. Two industrial effluent samples gave mean recoveries of 1.93 μg/l and 63.1 μg/l, with respective standard deviations of 0.21 and 3.1.

When the low-level samples were dosed with 5 μg of Aroclor 1242/l, the mean recovery was 90%, with a standard deviation of 0.58. River waters dosed with 1 μg/l gave mean recoveries of 105%, with a standard deviation of 6.4. With the use of an air-dried — soxhlet extraction method, 96% of a 240 μg/kg dose was recovered from lake bottom samples.

Organic Analytical Manual

Work on compiling analytical methods to determine specific classes of organic compounds, including expansion of the 1971 pesticide analytical manual, was begun. Eight individual methods prepared last year for the analysis of industrial effluents are being modified to cover a broad range of sample types: organochlorine; organophosphorus; organonitrogen (triazines, carbamates, and ureas); phenoxy acid pesticides and herbicides; and organochlorine solvents and polychlorinated biphenyls. New methods for benzidine and its salts and for volatile organics including vinyl chloride will be included. Methods for other specific compounds and compound classes will be added as they are developed and evaluated.

Advanced Instrumentation

Nearly all of the effort of the section was devoted to analytical methods development with computerized GC/MS and to the pilot laboratory automation project. The applications of GC/MS are featured in an article following this laboratory's report.

The application of powerful instrumentation in any field of endeavor requires the implementation of quality assurance techniques and GC/MS is no exception. A quality assurance procedure for GC/MS was developed previously at MDQARL. This procedure depends on the use of a standard reference material, which was also developed at MDQARL, to make a rapid (about 15 min) check of the performance of the complete GC/MS operating system. This year an improved version of this procedure was developed and a much purer sample of the reference compound was acquired. The procedure and reference sample were distributed to many EPA laboratories across the country and to a number of other laboratories that requested it.

For many years scientists concerned with water pollution wished for a method to identify organic pollutants that employed a simple, inexpensive, and fast examination of the unaltered water. Although this ideal method is still a long way off, progress has been made toward the goal. A study of direct aqueous injection GC/MS was begun at MDQARL this year. This very fast method of analysis could lead to a relatively low unit cost analysis in spite of the high cost of equipment. Currently there are at least three significant limitations to the technique. The current detection limit is approximately 1 mg/l and may vary upward to about 50 mg/l for some compounds. This limits the current method to general surveys of waste samples containing relatively high concentrations of organic compounds. If a sample is being analyzed for a specific compound, special techniques are developed that lower the detection limit to about 50 μg/l. Another limitation is that the organic compounds absolutely must be sufficiently volatile for gas chromatography. Finally, a computerized GC/MS system is required. Although the cost of these systems has decreased significantly in recent years, they are nevertheless complicated to use and require a skilled and full time staff.

Work was begun on a procedural manual designed for personnel that use the computerized GC/MS to identify organic environmental pollutants. New procedures and techniques that have been developed as well as older information will be incorporated. Leadership was provided in EPA applications of GC/MS through an informal mass spectrometer users group. Two meetings were organized and several newsletters were compiled and distributed; the purpose was to encourage the exchange of information and of new applications of GC/MS.

The development of a laboratory automation system was also begun this year. The purpose of this is to develop and demonstrate a method to provide many more chemical environmental analyses with improved accuracy, better precision, higher sensitivity, more timely results, greater selectivity, and overall lower unit costs.

QUALITY ASSURANCE AND LABORATORY EVALUATION

The Quality Assurance and Laboratory Evaluation (QALE) Branch's quality assurance program for water and waste analyses is accomplished by (1) conducting formal method validation studies; (2) maintaining an ample quality control check sample program; (3) developing an EPA interlaboratory performance evaluation program; and (4) developing the necessary guidelines and manuals for analytical methods, analytical quality control, sampling/sample preservation.

Method Validation Studies

In 1974, studies were performed on: the cold vapor technique for determining mercury in water, emission spectroscopy for determining trace metals, chlorophyll measurements by spectrophotometer and fluorometer, and identification of fresh-water macroinvertebrates.

Quality Control Check Samples

Quality Control (QC) samples are provided to water laboratories for use in their within-laboratory QC programs. In 1974, 13,000 sample concentrates were distributed to EPA laboratories and to Federal, State, and private laboratories (Figures 59-62). New reference sample work began on the specific pollutants: cyanide, phenols, vinyl chloride.

Expanded environmental monitoring has increased the demand for more samples and different samples; this has resulted in contract procurement of petroleum hydrocarbon (American Petroleum Institute selected crude oils and oil fractions), water sediment and mineral/physical reference samples and referee laboratory services.

Figure 59. Printout, analytical balance used in sample preparation.

Guidelines, Manuals, and Interlaboratory Quality Control

With the beginning of the compliance monitoring program in 1974 under the NPDES, there was an increased need for an expanded quality assurance program to make certain that NPDES monitoring data are of the highest quality. Toward this end, a new section in the QALE Branch was established for development of quality assurance contracts. These contracts include:

- guidelines of sampling and sample preservation techniques for all water analyses from which the products will be a state-of-the-art report and an EPA handbook,
- a study of the feasibility of an EPA certification program,
- development of a protocol system for on-site inspection surveys of EPA field and laboratory functions,

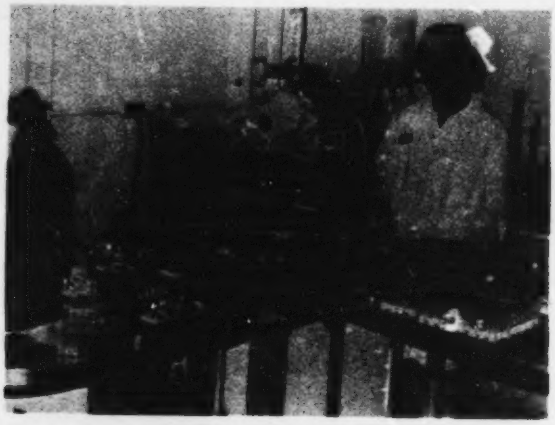


Figure 60. Automated preparation of samples in ampuls.

- contract for a system of performance evaluation testing of all EPA laboratories,
- contracts for computer services to support an EPA data handling system project (ALMS) and for purchase of the computer hardware needed for the current EPA laboratory automation project, and
- a contract (completed) for technical editing and writing of the first EPA *Manual of Microbiological Methods for Analyses of Water and Waste*. The manual will be reviewed by Agency microbiologists.

Paper surveys detailing personnel, facilities, program and quality control were followed by onsite laboratory evaluations of 6 of the 10 EPA Regional Laboratories. The summary reports of these evaluations (by the NERC quality assurance team of specialists in air, water, pesticides, and radiation) provided an up-to-date measure to the EPA Office of Research and Development and to the Regions of the laboratory capabilities and recommendations for improvement.

Figure 61. Metals analyses by AA spectrophotometer.

BIOLOGICAL METHODS

Virology Section

The Virology Section has as a prime responsibility the development of a system by which low levels of human viruses can be detected quantitatively in waters of varying quality. We have set as our tentative goal the detection of 1 plaque-forming unit (PFU) of virus per 100 gal of water. This is based on our assessment that detecting 1 PFU/100 gal is an attainable goal, not on the assumption that water with less than that amount must be safe. As yet no one system has proven sensitive enough to efficiently concentrate virus from the wide range of water qualities to which the method must be applied.

Figure 62. Sample mailing to Federal, State, and other laboratories.

Of the systems that have been subjected to extensive evaluation and refinement, the most sensitive to date has been the membrane filter system shown in Figure 63.

Viruses associated with feces, sludges, and other solids in water pose additional problems when developing reliable detection and monitoring methodology. Monitoring of these solids is important, for often more viruses adsorb to solids in the sampled waters than are found in the waters themselves. Figure 64 shows solids being removed for subsequent virus extraction; the techniques were developed in conjunction with the membrane filter.

Figure 63. Membrane filter system used to concentrate virus from water.

Because small amounts of viruses ejected into rivers and streams are potential hazards to downstream recreationalists and consumers, it is quite evident that to provide adequate protection, treatment processes must be efficient in destroying these agents. Effective results were observed when the solids contact module at the Dallas, Texas, Water Reclamation Center was evaluated for virus removal. The study, carried out by seeding with poliovirus, demonstrated that high-lime treatment is capable of achieving a very high degree of viral removal and is markedly superior to an alternate treatment with alum. Moreover, no viable poliovirus could be recovered from lime sludge samples taken at optimum viral dosage times. Microbiologically, these results suggest that the high-lime process could be applied to the renovation of wastewaters.

In a study, prepared for the U.S. Army Natick Laboratory, on the effects of iodine and chlorine on coxsackievirus A9 and its infectious nucleic acid (RNA), both chlorine and iodine gave effective inactivation rates (halogen concentration vs. 99% inactivation time) for intact virus. Chlorine was also a rapid inactivator of coxsackievirus A9 RNA, whereas the iodine rate was too slow to be measured accurately. In further contrast to iodine disinfection, coxsackievirus A9 proved more resistant to chlorine than did its infectious RNA.

Figure 64. Removing solids for later virus extraction.

Primary and continuous cells constitute the two basic types of cell culture systems used in viral research. Both cell culture systems have advantages and disadvantages. The one used depends on many factors, the most important of which is the susceptibility of the cell system to the viruses studied. Primary kidney cell cultures from African green and rhesus monkeys have served as the major laboratory systems for recovering enteroviruses and reoviruses. Charged with improving existing virus methodology, we sought to establish a continuous cell line that would be at least as sensitive as these primary cells to enteroviruses and reoviruses. Far exceeding our expectations was the BGM cell line established from primary African green monkey kidney cells by Dr. Almen Barron of the University of Buffalo. This continuous cell line showed superior viral sensitivity and was far superior to commonly used primary monkey kidney cell cultures in securing effective viral recovery from sewage, sewage effluents, and natural waters. Discovery of this practical application of the BGM line exemplifies the importance of basic research in bringing about innovations in monitoring environmental conditions.

Aquatic Biology Section

The Aquatic Biology Section is responsible for the development of biological methodology used in both marine and fresh waters in routine field and laboratory work arising during short-term enforcement studies, in effluent testing, and in compliance and long-term water quality monitoring. These methods deal primarily with the collection, counting, and identification of aquatic organisms; measurements of organism biomass and metabolic rates; measurements of the toxicity, bioaccumulation, and biomagnification of pollutants; and processing and interpreting biological data. Methods development and evaluation are accomplished through grants, contracts, and in-house research. The aquatic biology methods research program is assisted by an advisory committee of senior EPA biologists selected from the national field investigation centers, and from national research and regional surveillance and analysis programs. The committee meets annually to review the aquatic biology methods research program and to select methods to be included in the EPA biological methods manual.

Biological Methods Manual

Revision of the EPA manual, *Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents,* began in January 1974. New material that will be added includes non-parametric statistical analyses, computer programs for data handling, techniques to measure adenosine triphosphate (ATP), static and flow-through bioassays for effluents, and methods for tissue analysis. The second edition of the manual is scheduled for publication in 1975.

Sample Collection And Processing

The collection of periphyton in field studies is currently hampered by the lack of commercially available sampling devices. This problem was discussed with sampling equipment manufacturers, and several prototype samplers were developed. The results of field tests of these samplers are encouraging, and several models should be commercially available for the 1975 sampling season (Figure 65).

Methods Of Organism Identification

A manual containing extensive ecological information, pollution tolerance ratings, and keys for the identification of *Stenonema* mayflies was completed in-house and is scheduled for publication in the EPA Environmental Monitoring Series early in 1975. This manual will be useful to water pollution biologists in processing field samples and interpreting biological data collected in enforcement surveys and ambient water quality monitoring. Also, the manual, *Keys to the Water Quality Indicative Organisms, Southeastern United States,* originally published in 1968 by the National Training Program, was revised by our program and will be published early in 1975 because of the continuing high demand.

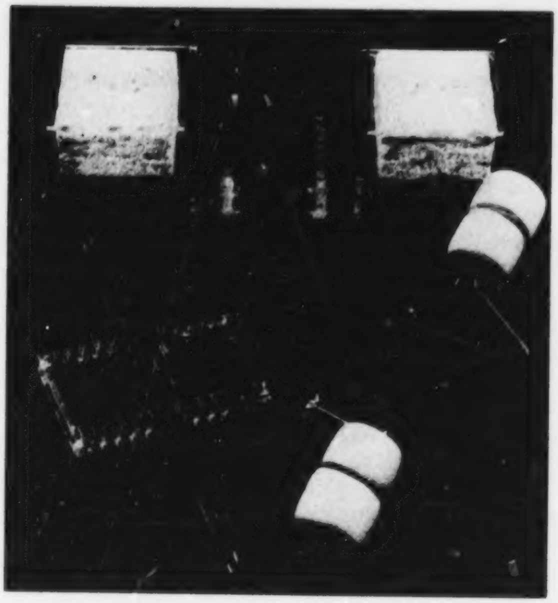


Figure 65. Commercial prototypes of periphyton samplers.

Measurements Of Biomass And Metabolic Rates

Grants were awarded to the University of Cincinnati to develop methods of phytoplankton pigment separation, identification, and quantification to be employed in determining phytoplankton biomass, taxonomic composition, and physiological condition. Work also continued on in-house projects concerned with the evaluation of ATP and other plankton biomass parameters.

Bioassay, Biomonitoring And Bioaccumulation

The Bioassay Subcommittee of the Biological Advisory Committee reviewed available bioassay methodology and prepared recommendations for a static and flow-through effluent bioassay to be published in the Federal Register in conjunction with the revision of the 304(g) regulations. These bioassays will be used for self monitoring by industry, under Section 308(a) of Public Law No. 92-500, and for compliance monitoring by the EPA and State programs.

Data Processing And Evaluation

A contract was awarded for the development of software for a biological data storage and retrieval system for the EPA computerized water quality data handling facility (STORET). This task is the final phase of a project initiated in 1973, and the system, called BIO-STORET, is scheduled to become operational in 1975. It will be used by EPA and other Federal and State agencies to store biological data collected in enforcement studies, and in compliance and ambient water quality monitoring.

Microbiology Methods

To carry out its role in the development and evaluation of improved methods for the identification of pathogens and indicator microorganisms, the Microbiological Methods Section dealt with several problem areas.

Erratic results have been reported when the membrane filter (MF) technique is used to determine the sanitary quality of chlorinated effluents, a problem of particular concern to the effluent monitoring program. An in-depth study on five sewage treatment plants confirmed that the standard MF procedures for determining total and fecal coliforms are not applicable to these wastewaters. The standard MF test gave results consistently below the lower 95% confidence limits of simultaneously determined most probable number (MPN) values. Analysts are presently restricted to the more cumbersome MPN procedure. The continuing investigation shows promise of producing an improved MF test utilizing optimum temperature acclimation and media modifications.

Because of the emphasis on more rapid and simplified methods for detecting and identifying pathogens, newly available, commercially prepared multiple-test systems were evaluated for the identification of *Salmonella* from water. The AP Enteric 20, Enterotube, Auxotab, and r/b Diagnostic Systems identified *Salmonella* with 100%, 90.0%, 93.8%, and 92.4% accuracy, respectively. Two other multitest systems are now being incorporated into the evaluation study.

When the most commonly used enrichment and selective media for the detection of *Salmonella* were compared, the combination of dulcitol selenite enrichment with brilliant green agar was shown to yield the most efficient system for recovering *Salmonella* from surface waters. It is still recommended, however, that more than one enrichment and selective plating medium be used for isolating enteric pathogens. Pure cultures and natural samples are being used to determine the sensitivity and optimum recovery time of the enrichment media employed.

The laboratory has funded a research grant to complete the development of a direct-staining fluorescent antibody procedure for fecal streptococci with the use of specific strains and labelled conjugates. This procedure will provide a more rapid and direct test for fecal streptococci that will distinguish human from animal pollution sources.

A research project has been initiated to develop a primary plating medium and test procedure that will enumerate and differentiate *Klebsiella* from closely related coliforms and other bacteria in water. The procedure will enable microbiologists to assess the true significance of *Klebsiella* in the environment and to determine the public health hazard in certain industrial discharges where *Klebsiella* proliferate.

To encourage uniform test procedures and ensure valid, reliable microbiological data, laboratory personnel have actively participated in the formation of methods selection groups among EPA microbiologists and in the preparation of an EPA microbiological manual to be published. Continuing evaluations are conducted to ensure the quality of materials and supplies used in commonly applied microbiological tests. Microbiologists participate in American Society for Testing and Materials activities to promote the development of standard test procedures for MF's and other materials.

RADIOCHEMISTRY AND NUCLEAR ENGINEERING BRANCH AND FACILITY

The Branch, combined with the Radiochemistry and Nuclear Engineering Facility of the Office of Radiation Programs, undertakes field studies to measure population radiation exposure, obtain information to provide guidance for achieving lowest practicable exposures, and develop and test monitoring procedures. The program of activities in 1974 consisted of completing the long-term generic studies at boiling water reactor (BWR) and pressurized water reactor (PWR) nuclear power stations; planning an extension of these studies to a high-temperature gas-cooled reactor (HTGR) and a fuel reprocessing plant; continuing a special study at a BWR station of the pathway of airborne ^{131}I from stack to cow's milk; beginning activities in support of the radiological aspects of the proposed drinking water standards; and supporting studies at a radioactive waste surface burial facility.

A report was prepared presenting the results of the radiological surveillance study at Haddam Neck, a 600 megawatt (electric) PWR nuclear power station. In-plant, effluent, and environmental radionuclide measurements were reported, surveillance procedures were described, and population radiation exposures were estimated on the basis of pathway models. The critical radionuclides and pathways for radiation exposure were indicated, and monitoring activities were recommended. This is the third of four studies at commercially operated nuclear power stations in the program. Measurements at the fourth station, a BWR, have been completed, and the draft of the report is being prepared.

The generic study at the HTGR nuclear power station has been postponed until next year because of delays in the initial full-power operation of the station. The planned study at the fuel reprocessing plant has been postponed indefinitely because of the failure of the Midwest Fuel Recovery Plant to begin operation. As a result of this, no commercial reprocessing plant will be operating in the United States for several years.

The initial study of the ^{131}I air-milk pathway at the Dresden BWR nuclear power station in the summer of 1973 (see 1973 Annual Report) indicated several problem areas that were examined during the summer of 1974. In preparation, methods were developed for measuring ^{131}I to levels as low as 0.03 and 0.09 pCi per sample for 1,000- and 100-min counting periods, respectively. This was achieved for grass and milk samples by chemically separating radioiodine with iodine carrier, precipitating palladium iodide, and counting with a beta-gamma coincidence system. The latter consists of a 5-in-diameter well-type NaI(T1) gamma-ray detector with phototube and a plastic scintillator beta-particle detector with phototube inserted into the well. Twenty-liter samples of milk and grass from 1 to 2 m^2 areas were analyzed.

The continuation of the study was performed in cooperation with the U.S. Atomic Energy Commission (AEC) and the station operator at the Quad Cities nuclear power station near Moline, Illinois. Sampling points were located approximately 0.8, 1.6, 3.2, and 8 km distant from the station, and a "background" point was located 29 km distant. Grass and rainwater were collected at all four locations near the station, and milk, at two of them. The AEC collected and measured airborne radionuclides. The station operator and the AEC measured ^{131}I releases and distinguished the chemical forms of the ^{131}I at the two points of discharge, the stack and the roof vent at the station.

The study provided information on the influence of the chemical form of the ^{131}I (I_2 vs CH_3I), the point of discharge (stack vs vent), the form of deposition (dry vs wet), and the amount of ^{131}I in milk as a function of distance from the station. Some complications were introduced in the data analysis by atmospheric nuclear tests by mainland China and France, which introduced ^{131}I into ground-level air at the station during the study period.

Analytical methods for measuring the radionuclides ^{90}Sr, ^{131}I, ^{134}Cs, ^{137}Cs, ^{226}Ra, and ^{228}Ra at levels of approximately 0.1 pCi/l were tested in preparation for the requirements of proposed EPA drinking water standards. To provide a relatively simple method, method development was required specifically for radium analysis.

A program to study the effectiveness of radium removal by routinely used processes for treating public water supplies was begun with contracts to two State agencies. Water supplies that contain approximately 10 pCi ^{226}Ra/l were selected to provide precise data for radium removal. Other selection criteria included the availability of various common treatment processes, the size of treatment plant, and ability to collect all required samples before, during, and after the process, and in the wastes. The Water Supply Research Laboratory, which is cooperating in this study, provides guidance and obtains samples for analyzing nonradioactive constituents. Results will be available next year.

The Kentucky Radiological Health Program's study of the behavior of radionuclides at the Maxey Flats radioactive waste disposal site was supported in two aspects. First, assistance was provided in preparing a computer-stored inventory with programs for data analysis. Because the inventory includes approximately 200,000 items in various tabulations, even the accuracy of the initial inventory lists required a major effort. Secondly, a program of measurements of airborne radionuclides at the site was initiated to permit distinguishing among three potential pathways for radionuclides—movement in underground water, surface water, and air. Tritium in water vapor and radionuclides on airborne particles are measured at the source and in the environment. The study is to be completed next year.

INSTRUMENTATION DEVELOPMENT BRANCH

As one of five branches within MDQARL, Instrumentation Development is concerned with developing and demonstrating new monitoring instruments for detecting pollutants in environmental media; developing guidelines and programs for use of such prototypes and production models of selected measurement instrumentation; and telemetering and data-handling functions.

An ISCO Model 1391 wastewater sampler and associated flowmeter (Figure 66) were investigated for temperature stability under laboratory conditions. Under all conditions, spurious signals traced to a magnetically operated relay caused erratic sample acquisitions, high humidities affected sampler operation, and decreasing flows decreased flowmeter precision.

A Honeywell dissolved oxygen parametric system was investigated in the laboratory and in the

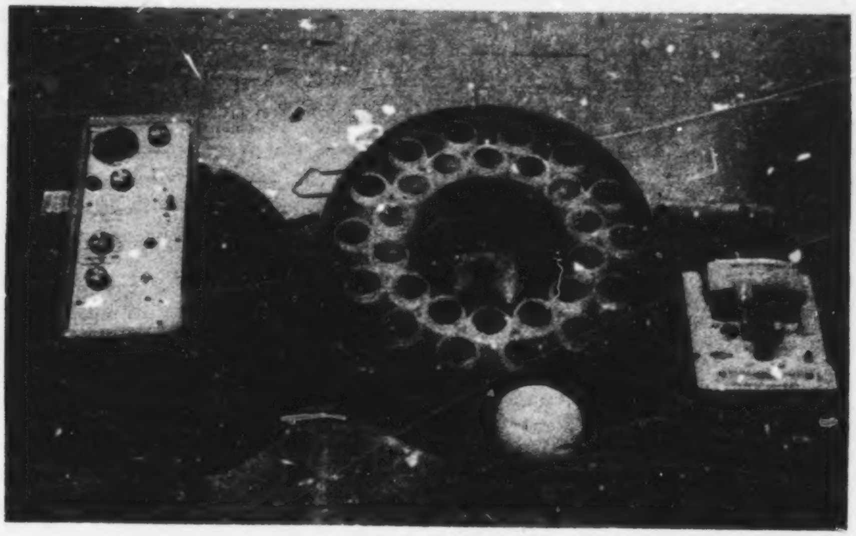


Figure 66. ISCO Model 1391.

activated sludge basin, the chlorinated effluent raceway (Figure 67), and the secondary settling basin of the Hamilton, Ohio, Sewage Treatment Plant. The Honeywell design is unique; signal current from the passive cell, which produces a temperature-compensated millivolt potential at the source, is filtered in the analyzer and is converted into alternating current by synchronized field effect transistors (FET's). The modulator—demodulator FET's are driven by a 200 cycles/sec free-running multivibrator. The output integrates to about 5 volts direct current for full-scale dissolved oxygen of 10 to 20 mg/l.

Performance in the activated sludge basin was satisfactory but manual sensor maintenance caused a 2- to 4-hr period of erratic operation as spikes (rapid changes in recorded signal) 25% of full scale developed. Spikes did not occur when the sensor was chemically cleaned in a pH 2.5 solution without manually wiping the membrane (Figure 68).

An instrumentation system for field measurement of cyanide concentration, developed by Orion Research, was investigated. The system (Figure 69) was designed to duplicate laboratory analyses made with ion-selective electrodes. The sensor, comprised of a silver/sulfide and sodium reference electrode set, is employed in the indicator method to detect cyanide. Although cadmium, copper, nickel, and zinc metal complexes of cyanide are broken by adding chemical reagents, tightly bound cyanide complexes of iron, cobalt, and platinum are not.

Under controlled laboratory conditions, this cyanide monitor was electronically stable within

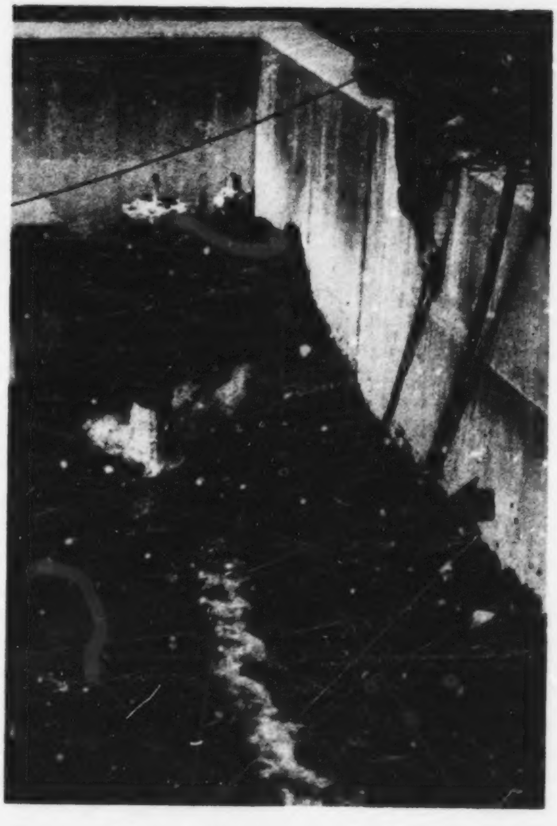


Figure 67. Honeywell dissolved oxygen sensor (arrow) installation at Hamilton, Ohio, Sewage Treatment Plant effluent raceway.

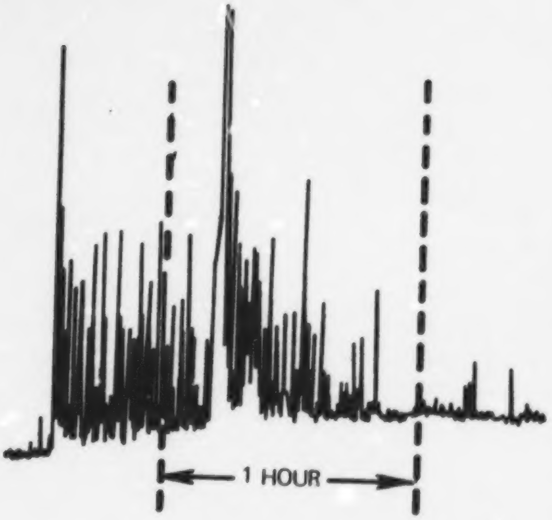


Figure 68. Effect of cleaning on Honeywell sensor.

0.1% over a temperature range of 5°C to 35°C. The sensor was tested with the use of cyanide standards over a similar temperature range. Performance was within Orion's stated tolerance of ±10% of reading. Dynamic measurements of a metal plating stream were periodically compared with measurements made by the "total cyanide" chemical procedure of samples being taken before and after the filter function of the monitor. Steady state comparisons indicated a 15% to 20% loss in cyanide concentration across the sample input filter required by the monitor.

A cooperative effort in field investigation of an EPA Martek monitor was initiated with the National Park Service. The system continuously measures depth, dissolved oxygen, conductivity, pH, and temperature. The system, to be investigated on the Potomac River, will be operated from one of several Park Service ships (Figure 70) and will provide District of Columbia high school and college students an opportunity to work with water quality instrumentation.

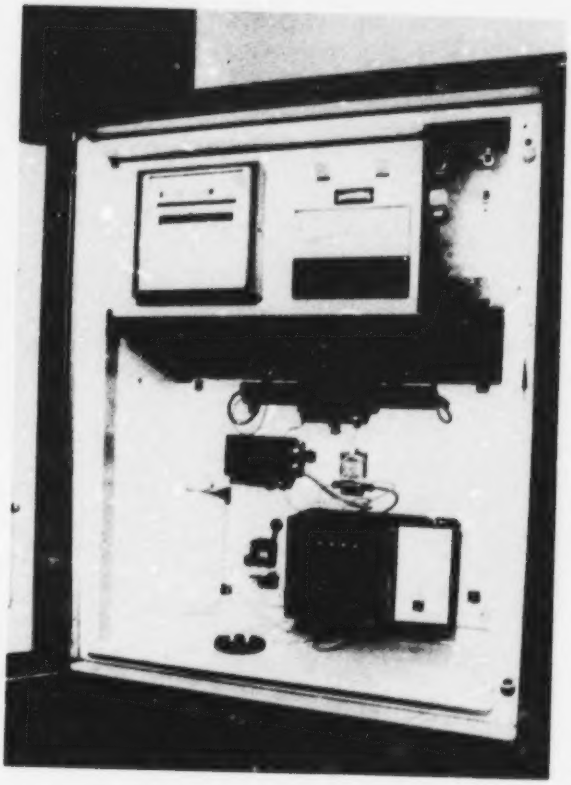


Figure 69. Orion cyanide monitor.

Figure 70. One of the National Park Service river craft being used to field test the EPA Martek monitor.

identifying organic pollutants with computerized gas chromatography/mass spectrometry

The identification and measurement of the concentration of specific organic compounds that contaminate the environment has concerned environmental research scientists for many years. Gross measurements of organic pollution such as the chemical oxygen demand (COD), biochemical oxygen demand (BOD), and total organic carbon (TOC) tests are of no value in situations where information is needed about specific pollutants. Firm identifications are required to determine the causes of taste or odor in drinking water, to elucidate the distribution of toxic compounds in surface or waste water, to study the accumulation of persistent compounds in wildlife tissue, to discover the causes of fish kills, to evaluate the effectiveness of treatment facilities in removing classes or specific types of compounds, to map the specific sources of organic pollutants, to determine the degradation mechanisms of pollutants, and to enforce effluent standards for toxic organic compounds.

The earliest approaches to specific identifications and measurements were based on detailed chemical-instrumental procedures that were designed to separate the compound of interest from all of the other compounds present and measure its concentration with relatively inexpensive instrumentation. The colorimetric 4-aminoantipyrine derivative procedure for phenol and the electron capture detector — gas chromatography procedures for chlorinated hydrocarbon pesticides are typical examples of this approach. Although these specialized techniques are justified for compounds of special significance (e.g., pesticide residue analyses in foods), there are several inherent limitations to the approach. To include all environmentally significant compounds, literally thousands of detailed procedures would have to be developed, tested, and documented. The procedural manuals alone might require dozens of volumes. Implementing these procedures to analyze for all components of an environmental sample would be extremely slow and costly. This approach includes no provision for finding new environmental contaminants except by pure chance of an unexpected interference in a particular method. Invariably interferences do occur, e.g., the polychlorinated biphenyls seriously interfere with chlorinated pesticide methods and many but not all phenols form 4-aminoantipyrine derivatives.

With the development of the environmental concern of the late 1960's, it was recognized that general methods of high information content were required to facilitate the economical analysis of a wide variety of organic pollutants. The use of the mass spectrometer as such a detector for the gas chromatograph (GC/MS) was developed during the 1960's. The mini-computer was invented during this time and applied to GC/MS to utilize the enormous wealth of information produced by the mass spectrometer. Computerized GC/MS quickly revolutionized the field of trace organic analysis and made very significant contributions to research in medicine, biochemistry, flavors, odors, and organic geochemistry.

Beginning in 1971 the U.S. Environmental Protection Agency (EPA) made a major commitment to computerized GC/MS for organic pollutant analysis. Over 20 systems were installed in laboratories across the country. The labs included the Regional Surveillance and Analysis Facilities—which carry out EPA's monitoring function, several field investigation centers—which are part of the enforcement arm of EPA; several pesticide laboratories; and a number of research and development facilities.

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Like any automated method, computerized GC/MS does not reduce the need for skilled manpower. In the field laboratories, GC/MS equipment is under the supervision of a chemist with an advanced degree or equivalent experience. Research support for field labs is required from multidisciplinary teams of spectroscopists, analytical chemists, electronics engineers, and laboratory mini-computer specialists in research and development laboratories. The major advantage of the technique is that it substantially increases the capacity of a staff of fixed or limited size to make increasingly large numbers of accurate identifications of specific organic compounds in environmental samples.

Identifying pollutants at the part-per-billion level with a high degree of confidence has become almost routine in more than a few EPA laboratories. What was once a nearly impossible task for a staff of 100 working for 6 months sometimes can be accomplished by a skilled individual in a few hours.

Most of the systems installed in EPA laboratories use Finnigan Quadrupole Mass Spectrometers controlled by Digital Equipment Corporation PDP-8 mini-computers (Figure 71). However, some Varian and Hewlett-Packard (H-P) spectrometers are used with Varian 620 and H-P mini-computers.

The gas chromatograph is very well established as a powerful tool for separating mixtures of volatile organic compounds. However, since conventional GC detectors provide no qualitative information about the sample, they are either removed entirely or used only during solvent venting or other ancillary functions.

As is true for conventional GC detectors, the mass spectrometer is very sensitive. In contrast to the single channel response of most conventional GC detectors, the mass spectrometer provides a multichannel response (abundance measurements of ions of different masses) that carries a great deal of information about molecular structure and composition of organic compounds. This information may be displayed graphically by a fast cathode ray tube or a hard copy plotter, printed in digital form, or transmitted over concentional voice-grade telephone circuits to other data handling systems.

In noncomputerized GC/MS systems, mass spectra generally are not acquired continuously during a GC run. Continuous mass spectra acquisition generates very significant information that cannot, however, be processed economically or accurately by hand. This dilemma is solved in a computerized system. Mass spectra are acquired continuously; the mini-computer simultaneously handles all information and controls the operation of the quadrupole spectrometer. Data are stored temporarily on a magnetic disk or a magnetic tape before background corrections are made and before data are output by plotting, printing, or transmission. Personnel who previously devoted long frustrating hours to manual data processing are freed to do productive tasks.

With the hardware and computer programs mentioned above, it still may not be possible to make valid identifications of organic pollutants. A basic assumption of this method is that the organic compounds are sufficiently volatile for gas chromatography. This assumption must be met if conventional GC/MS is to be useful.

Another basic assumption is that the chromatograph produces a clean separation of the organic

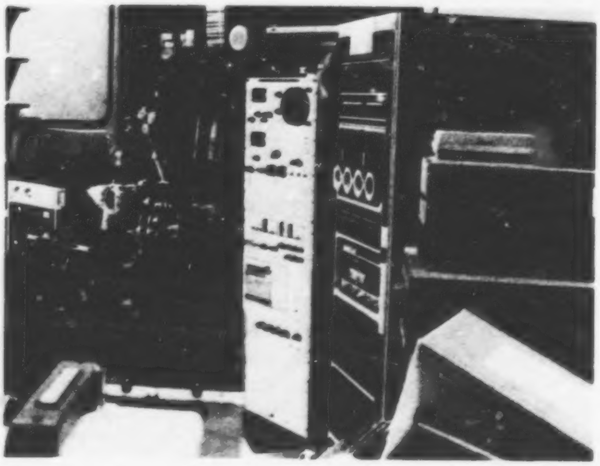

Figure 71. GC/MS system at NERC–Cincinnati.

components in a mixture. This is, of course, the classic problem of chromatography, but it is made somewhat more manageable with a mass spectrometer detector. An experienced user can frequently ascertain that the separation is clean and free of overlaps by examining the consistency of the mass spectra obtained at various points across the GC peaks. This is not possible with a simpler, conventional GC detector. By suitable background corrections, the GC/MS computer user usually can isolate both spectra of overlapping peaks.

The Methods Development and Quality Assurance Research Laboratory supports EPA's utilization of this equipment with a methods development program in GC/MS. Detailed methods are needed to apply this equipment to water and wastewater analyses. These methods are not and cannot be provided by the equipment manufacturers who are primarily builders of hardware that is applied in many different areas of investigation.

A good example of a new methods development is the direct aqueous injection analysis of industrial effluents. Recently, samples were received from a small lagoon that was being used as an industrial waste dump site and from leachate flowing into a stream adjacent to the lagoon. Literally in a matter of a few hours, eight organic compounds present in the lagoon were unambiguously identified and their concentration estimated. More importantly, one of the compounds, a common industrial solvent, was clearly identified as a contaminant in the small stream, which was used as a drinking water supply by local farmers. The key points in this illustration are the speed, accuracy, and very low unit cost that was obtainable in this organics analysis with computerized GC/MS.

solid & hazardous waste research laboratory

The Solid and Hazardous Waste Research Laboratory (SHWRL) is responsible for research into new and improved systems of solid and hazardous waste management and for the development of technology, determination of environmental effects, and collection of data necessary for the establishment of processing and disposal guidelines. In the past, the laboratory concentrated on problems associated with municipal solid waste, but recently the emphasis has shifted. With present efforts directed primarily toward the environmental effects of waste disposed onto or into the land, SHWRL has undertaken research to develop disposal or treatment technologies that will minimize or prevent harmful effects.

The problems of solid waste disposal are interrelated with those of air and water pollution. Incineration, grinding, the use of water for either transportation of solids or as a solid waste sink — these impinge upon the concurrent attempts to purify the air and water environments. Additionally, the elimination of impurities from air or water effluents as the sources of pollution results in the generation of solid wastes by such processes as separation, drying, or compaction — solids that in turn, require disposal. Measures to reduce pollution or dispose of waste material must, therefore, be taken with full consideration of the effect on the overall environment — air, water, and land.

The solid waste problem is concentrated in densely populated urban areas. Refuse storage, collection, transportation, and processing directly and intimately affect some 80% of the population. The costs of waste handling, already severe, are rising. The loss of billions of tons of material to unreclaimed waste each year indirectly affects each consumer.

Municipal solid waste is delivered to the EPA Center Hill facility (Figure 72, top left) and characterized for physical (Figure 73, top right) and chemical composition. Gas and temperature sensors and the solid waste are placed in 1.8-meter-diameter test cells (Figure 74, center left) that simulate a sanitary landfill cell. Several test cells contain hazardous wastes; virus survival is to be determined by placing plastic exposure tubes (Figure 75, center right) containing virus-seeded packets of solid waste into the compacted solid waste (bottom left, Figure 76, looking down into test cell). Leachate and gas volumes and solid waste temperatures are monitored for an extended period of time (Figure 77, bottom right). Composition of leachate and gas are also monitored to provide information on the fate and decomposition of solid and hazardous materials.

LAND DISPOSAL OF MUNICIPAL SOLID WASTES

The overall objectives of this project are to assess the potential environmental damage caused by disposal to the land of municipal solid waste; identify, develop, and describe appropriate technology to protect against such damages; and to assemble information on environmental damages and control technology. Three research programs were assembled during 1974 to achieve these objectives: 17BAZ-Environmental Effects of Leachate Generated by Landfill; 24AAG-Environmental Effects of Gases Generated in Solid Waste Landfills; and 24ALH-Environmental Effects of Sludge and Hazardous Waste Disposal by Sanitary Landfill. These programs were designed to provide information on rates and quality of gas and leachate generated from municipal solid waste alone and in combination with selected hazardous wastes, and on methods that can be used to measure and control these emissions.

Information transfer among the various researchers in this field is aided by a review of significant articles in the field published in the Journal of the Water Pollution Control Federation. Previous efforts have resulted in development of bibliographies on landfill gas and water quality. Compilation of the various analytical methods used to identify the constituents in leachate was initiated this year.

Specific nonprogrammed activities of the SHWRL staff in the land disposal projects include preparing a comprehensive report on gas and leachate production from municipal solid waste (available in June 1975); technically assisting Regions I and IV on enforcement actions; preparing a summary report on landfill research for Region I staff and State personnel; participating in University of Cincinnati Raymond Walters lecture series; participating in a solid waste training course for Region VII on leachate treatment design and research; and providing miscellaneous technical assistance for requests from citizens, local, State, national, and foreign governments, design engineers, and operating and regulatory agencies.

Leachate and Gas Production

Identification of leachate composition and production rates are the objectives of several specific projects. A long-term study performed at Drexel University has documented the quality and quantity of leachate producd from municipal solid waste. Results reported during the past year verified that leached material was reduced to the same low level as was observed the previous year (Table 6). In light of the low-level discharge characterized by a lack of biological activity, a program has been initiated to study the quality of leachate when the annual moisture regime (simulated rainfall) is accelerated to simulate 5 and 10 yr of leaching in a 1-yr period.

TABLE 6. LEACHATE CHARACTERISTICS FROM A BATCH SIMULATION SANITARY LANDFILL*

Characteristic†	Elapsed time since start of study, yr		
	1	4	5
pH	5.4	6.3	6.5
Fe	940	110	110
Cu	0.08	BDL‡	BDL‡
Na	990	104	57
Cl	258	65	32
Chemical oxygen demand	20,740	1,478	950
Residue	14,200	1,560	780
Ammonia-nitrogen	50.4	4.7	BDL‡
Organic-nitrogen	102	27.1	2.8

*Adapted from Fungaroli, A. A., and R. L. Steiner, *Final Report: Vol. 1. Investigation of Sanitary Landfill Behavior*, draft report submitted in partial fulfillment of Research Grant R800777, August 1974.

†All results in mg/l except pH.

‡BDL indicates detected although test was performed.

Leachate composition and production were also studied at the Boone County Field Site (BCFS) where large-scale, batch-type landfills cells are used. Results obtained during this year indicate a continued discharge of large concentrations of contaminants in leachate, although a downward trend appears to be developing. The results of this large-scale (Test Series 1) determination of leachate production compares favorably with the earlier laboratory study at Drexel University (Table 1). A second study at the BCFS (Test Series 2) was initiated to compare the performance of small-scale, simulated, landfills cells (1.8 m in diameter and 3.1 m deep, containing 3.6 tons of solid waste) with that of a large-scale landfill cell containing 113 tons. These facilities, constructed in 1972, were also monitored during 1974. Results of the 1974 monitoring indicate insignificant differences in leachate composition between the two types of cells, despite a significant difference in the duration of the elevated temperatures observed in 1972. These monitoring efforts will continue until the pollutants carried in leachate are reduced to low levels.

Additional leachate production studies (Test Series 3), originally scheduled as an in-house project, were initiated in 1974 by a contractor; the experimental facilities had been constructed under in-house supervision. The objectives of these studies are to evaluate, with the use of small-scale (3.6 ton) test cells, the influence of different moisture regimes and waste composition on leachate and gas production. Waste composition will be varied by introducing municipal wastewater sludges and hazardous sludges resulting from industrial processes and pollution abatement activities. Bacterial and virological studies will also be performed. It is anticipated that significant differences in mass flow rates of carbon dioxide and methane gases and the organic content in leachate will be observed. Such information is essential in assessing the environmental impact of sanitary landfills in a variety of climates and will also provide data necessary for the design of control systems when needed. Gas production data will also be useful in assessing the potential for methane recovery from sanitary landfills.

An additional source for obtaining gas production data was initiated in 1974, an effort, primarily, to determine gas production and, secondarily, to determine leachate production from baled and shredded solid waste (Figures 78 and 79). Experimental facilities are currently under construction, and the project is expected to be completed in 1977. Results from this project will be used to evaluate the environmental impact of baled and shredded solid waste in landfills.

Full assessment of the environmental impact of landfill gas requires that the extent of subsurface migration of these gases, particularly methane, be determined. Two-dimensional analysis of gas flow

Figure 78. Truckload of baled solid waste used in landfill simulation in Franklin, Ohio. Each bale weighed more than 1,100 kg (2,500 lb) and was compacted to a density greater than 890 kg/m^3 (1,500 lb/yd^3).

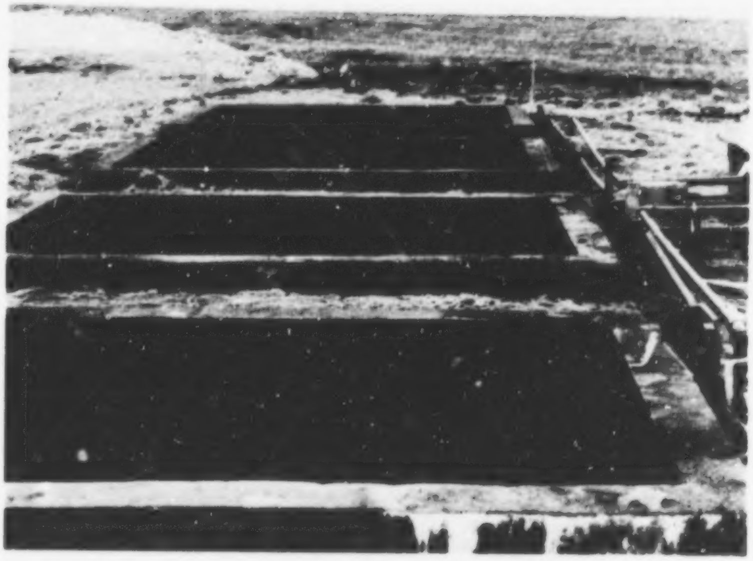

Figure 79. Test cells constructed at Franklin, Ohio, for landfill simulation studies.

through various combinations of soils and geological settings is being modeled and solved by using finite element analysis (Figure 80). Use of simulation techniques will generate graphs, charts, and tables. The product of this study, due to be completed in 1975, will be a user's manual whereby candidate landfill sites can be screened and specific sites can be more carefully evaluated.

Leachate Control

Methods for controlling leachate at landfills have also been studied during 1974. Two grantees at the University of Wisconsin are evaluating the use of traditional wastewater methods to treat leachate. They have concluded that anaerobic lagooning of fresh, highly contaminated leachate followed by aerobic polishing was most suitable for the typical landfill situation. A pilot plant was constructed to study the process parameters on a continuous operation and on a larger scale, and long-term operational data will be used to assess the feasibility of on-site leachate treatment.

From additional leachate treatment work in 1974 performed at the University of Illinois, data were obtained on the performance of anaerobic filters, aerobic lagoons, cotreatment with domestic wastewater, and various physical and chemical methods (Figure 81). Detailed characterization of the organic content indicated the presence of significant amounts of organic acids in fresh leachates and predominantly humic and fulvic acid-like materials in older, more stabilized leachate. Heavy metals were found to be associated with the fulvic acids and humic-like substances. The long-term operation of the anaerobic filter laboratory unit indicated

Figure 81. Leachate being transferred from holding pond to plant where treatment will consist of sand and activated carbon filtration, followed by spray irrigation.

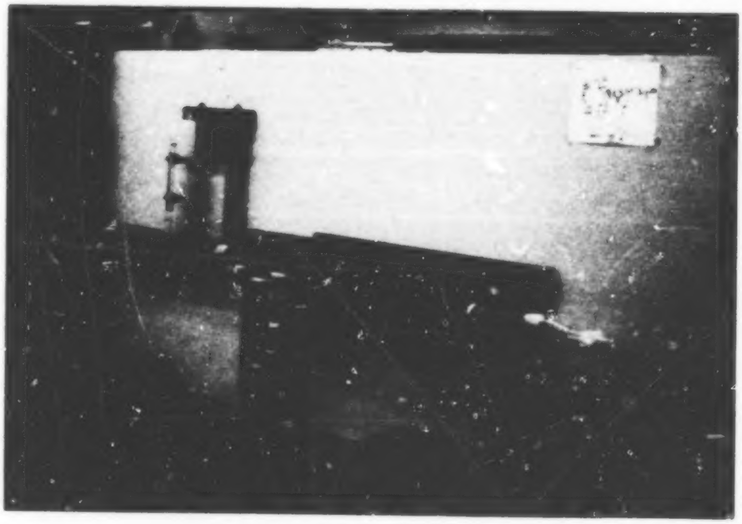

Figure 80. Experimental facilities for one-dimensional verification of landfill gas migration prediction model.

sulfide may be needed as a supplement to leachate to prevent the accumulation of toxic metals in the reactor.

Another study, completed in December 1974, evaluates the beneficial aspects of returning leachate to the solid waste in a landfill. The overall effect is that the rate of decomposition of the solid waste mass and the rate of reduction in the amount of organic material carried in leachate is increased. To satisfactorily increase the decomposition processes in the landfill, it was found that pH must be controlled. A pilot plant effort is anticipated during 1975. The shortened period of time for solid waste and leachate stabilization of organic matter is achieved by managing the landfill operation and controlling specific inputs (not usually employed in solid waste disposal) to the system.

Still another leachate control method evaluated was spray irrigation (Figure 82). This work was performed by in-house personnel, initially in cooperation with the University of Cincinnati. Results show that the quantity of leachate applied is controlled by the strength of the leachate rather than by the hydraulic loading. A range of 225 to 450 kg/ha/day produced no phytotoxicity. Percolate composition indicated a problem may be encountered with the conversion of ammonia and organic nitrogen to nitrate because high levels of nitrate are potentially hazardous. Greater than 90% reduction of all constituents were achieved with the exception of nitrate, which increased from 1 mg/l to 50 mg/l.

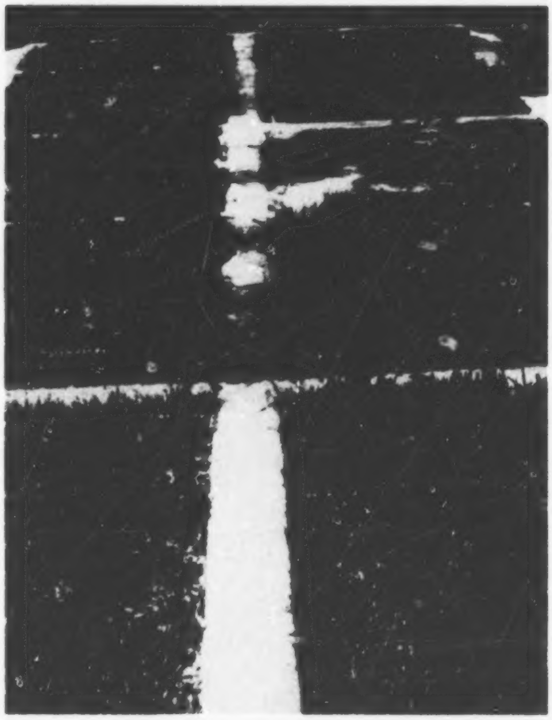

Figure 82. Pilot scale plots to determine the effect of solid waste leachate and gas on different types of cover material and vegetation.

Viruses and Bacteria

A study evaluating the presence and survival of human enteric pathogens (bacteria and viruses) was performed. The preliminary results indicate fresh leachate (high in organic acid content and slightly acidic) severely curtails survival of indicator organisms, but has a very slow, almost stabilizing, effect on polioviruses. In addition, the work concludes that EDTA should be used to preserve biological assay samples.

Compost Studies

Use of compost derived from municipal solid waste (Johnson City, Tennessee) was evaluated, and results indicate the possible accumulation of zinc and cadmium in corn leaf, grain, and cob when sewage-sludge-enriched compost is applied at 449 tons/ha. Lead, nickel, and chromium did not appear to have a detrimental effect. Studies, which are continuing into 1975, were performed in the laboratory/greenhouse and in the field. Tentative conclusions are that zinc and cadmium accumulations are not significant enough to hinder the use of municipal solid waste compost.

MIGRATION OF HAZARDOUS MATERIALS

Knowledge of the rates and extent of movement of hazardous materials in soils is of fundamental importance in formulation of hazardous waste management regulations and recommendations about the types of untreated wastes and unimproved sites suitable for land disposal. SHWRL extramural grant and contract activities that will supply this information cover three broad categories: (1) review and synthesis of available information, (2) studies under controlled conditions using actual wastes, and (3) field testing of conclusions drawn from the first two activities.

State-of-the-Art Reviews

The review and synthesis of available information provides a basis for tentative disposal recommendations. During the current year, two publications are being prepared: a partially annotated bibliography on migration and transformation in soil of selected heavy metals and pesticides and a report on present knowledge of migration of heavy metals in soil. A review of drafts of these publications supports the assumption that soil properties such as pH, texture, and content of oxides of iron and manganese will be important factors in the movement of heavy metals. Additionally, very little direct information is available on movement of heavy metals when accompanied by high concentrations of other soluble substances or on the movement of pesticides when applied to soil at rates higher than is common in agricultural practice. The conclusions drawn will be tested, and any needs for additional information will be satisfied during the controlled condition laboratory studies and the field studies currently planned or underway.

Controlled Lab Studies

Solid and semi-solid wastes are complex mixtures, and the leachates from them commonly contain high concentrations of hazardous materials along with high concentrations of other soluble substances that influence adsorption on soil colloids and other migration-related processes. The controlled condition studies, being conducted under interagency agreement at the Dugway Proving Ground, are using samples of actual industrial wastes to collect information that could not be obtained from the literature or from the laboratory work with single compounds and simulated wastes. Basically, these studies consist of leaching the wastes to determine the types and amounts of hazardous materials released (Figure 83). Some of the leachate is then applied to several different types of soils, and migration rates are observed so that an "attenuation coefficient" may be constructed describing the degree of hazard associated with a particular combination of waste and soil (Figure 84). Work is underway on wastes from five industries: mercury-cell chlorine production, electroplating, nickel-cadmium battery production, inorganic pigments, and water-based paints. The project will be expanded to include flue gas desulfuration sludges and wastes from at least 25 other industries.

Information from the first phase of the project indicates that none of the wastes studied to date should be disposed of under acidic conditions, and in particular, they should not be placed in municipal sanitary landfills.

At the University of Arizona and the Illinois State Geological Survey, the migration of municipal landfill leachate pollutants in whole soils and in mixtures of the basic soil clay minerals is being investigated. Leaching solutions used in these column-type experiments include natural municipal landfill leachate, a synthetic inorganic leachate, and a natural leachate "spiked" with various heavy metals (Figure 85). Objectives of the project are to evaluate pollutant attenuation by soils and to develop simulation models for the prediction of changes in solute concentration as leachate moves through soil. The results to date demonstrate that soil factors such as pH, texture, and content of iron oxides significantly influence migration of pollutants. The content of dissolved organic compounds appears to be the most important leachate factor affecting the solubility and mobility of heavy metal pollutants, with a higher content of certain organics favoring rapid migration. The rate of flow through soil, controlled primarily by soil texture, is another important factor in pollutant migration rates. Until some critical value is approached, decreases in flow

Figure 83. Columns used for a laboratory study of hazardous material movement in soils.

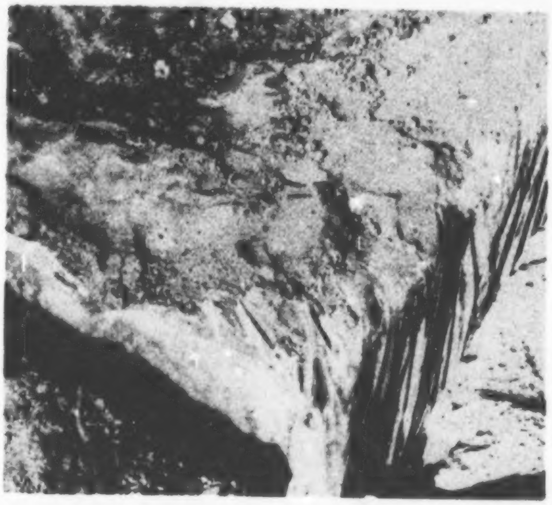

Figure 84. Constructing a test plot for field study of hazardous material movement in soil.

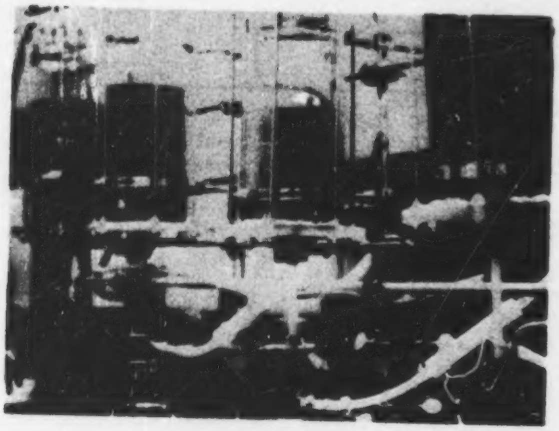

Figure 85. Columns used in a study of hazardous material movement through soil.

rate are associated with increases in attentuation, though in a nonlinear fashion.

Field Studies

Field studies, which are just being initiated, will run concurrently with the laboratory work and will examine the rate and extent of hazardous material migration from industrial disposal sites that are receiving many of the same wastes being studied in the laboratory. The objectives of these field studies are to check preliminary interpretations of the laboratory work, particularly the indication that disposal sites underlain by fine textured soils are suitable for certain types of wastes, and to point out gaps in knowledge and monitoring techniques that may require changes in on-going lab studies or initiation of new studies (Figure 86). The Illinois State Water Survey is conducting the first of these field studies. Pollutant migration patterns around and beneath a zinc smelting plant, an organic chemical plant, and a commercial hazardous waste disposal site are also being studied.

ENVIRONMENTAL EFFECTS OF SELECTED HAZARDOUS MATERIALS

Over the past year, a major emphasis of SHWRL's program has been directed to assessing the potential undesirable effects of waste materials intended for land disposal. A series of multimedia reports on the environmental effects and aspects of selected hazardous substances are thus being developed. The substances of interest are largely heavy metals and their compounds and pesticides: arsenic, asbestos, beryllium, cadmium, chromium, copper, cyanides, lead, mercury, selenium, zinc, aldrin/dieldrin, benzidine, DDD/DDE/DDT, endrin, PCB's, and toxaphene. Information on intermedia transport and concentration effects (dose responses) of these substances is needed to establish a scientific basis of support for regulatory and guideline programs directed toward their proper management.

Figure 86. Collecting samples at the EPA Boone County Field Site for use in laboratory studies of hazardous material movement in soil.

With the use of existing criteria documents and reports, Oak Ridge National Laboratories, under an interagency agreement, is compiling data on all environmental aspects of the selected substances into a single, integrated document, a Tabular Effects Data Matrix (TED). The purpose of the TED is to identify information gaps or inadequacies. Written reports on mercury and asbestos have been drafted and are being readied for extensive technical review; others will be completed in the next 2 years.

CONTROL TECHNOLOGIES FOR HAZARDOUS WASTES

The control technologies program evaluates and develops technologies to minimize adverse effects of hazardous materials discharged into the environment (Figure 87). Program objectives are to:

- report on acceptable disposal technology
- assess the adequacy of present technology (identify inadequate technology)
- develop new treatment/disposal technologies where present ones are inadequate
- develop and evaluate prototypes of promising technologies—those that maximize resource recovery.

As part of these studies, inadequate treatment/disposal technologies have been identified for toxic waste streams containing pesticides and for a number of organic metallic derivatives. Because in many instances treatment/disposal technologies are lacking, interim land storage of hazardous and toxic

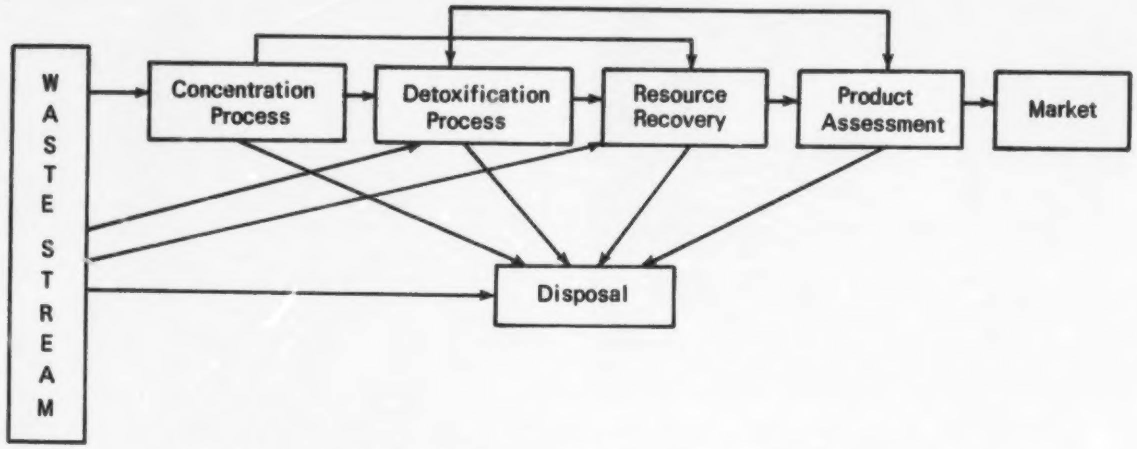

Figure 87. Scheme for processing hazardous waste for recovery, or disposal, or both.

waste is required. Considerations used in selecting promising techniques for development were inadequacy of present treatment, economics, resource recovery, and volume reduction. An in-house report on promising technologies for treating hazardous waste has been published.

Through an interagency agreement with Edgewood Arsenal, SHWRL is supporting studies to determine the effectiveness of new detoxification processes and the safety of byproducts recovered from hazardous material.

To fulfill requests for assessments of various technologies to manage hazardous wastes from an environmental standpoint, SHWRL has awarded two contracts. One is to Louis R. Reeder and Associates to compile available data with which to assess the technology of deep-well injection of industrial hazardous wastes into subsurface aquifiers. A similar study to Fenix and Scission involves assessing the technical feasibility of safely storing nonradioactive industrial hazardous waste in selected salt deposits and other rock deposits. A list of hazardous wastes developed by TRW Systems was used as a starting point to classify the waste into several categories—acceptable for underground storage in containers with or without treatment and unacceptable. The study results will require refinement; they do, however, indicate that hazardous, nonradioactive industrial waste can be stored with minimum risk to the environment.

PESTICIDE INCINERATION

A SHWRL contract awarded to Midwest Research Institute has produced experimental data relative to safe disposal of excess pesticides by incineration methods. Candidate pesticides in liquid and solid form (such as DDT, aldrin, picloram, zineb, and others representing 34 types in total) are test-burned in a special pilot-scale incinerator where process emissions are carefully monitored and analyzed. Such parameters as residence time, temperature, and excess air are studied to determine the conditions most conducive for the complete and safe detoxification of each formulation. Research thus far has shown the incinerator has remarkable ability to effect a 99.9+% destruction of several pesticides when operated in the 1,400°F to 1,800°F range with a ½- to 3-sec retention time. When completed, this work will form a major contribution to hazardous materials disposal technology.

RECYCLING: RESOURCE RECOVERY

Size Reduction

Although the SHWRL's program shifted emphasis during the year toward research in the management and control of hazardous waste, many resource recovery projects initiated in prior years were continued. Dr. George Trezek (University of California at Berkeley) completed sufficient research tests to enable development of basic theoretical relationships dealing with the size reduction of municipal solid wastes. He generated basic analytical data and relationships with regard to hammer and grate wear, particle size distribution, hammer speed, refuse feed rates, power consumption, moisture effects, and other associated aspects of the size reduction process. The data and analytical relationships are applicable to the design and operation of refuse grinders and facilities. Dr. Trezek is using the equipment and the facilities to assess the environmental health impact of refuse grinding and associated processes.

Specification

The National Center for Resource Recovery (NCRR) completed developing initial specification for materials separated from municipal solid wastes in resource recovery plants: folded newsprint, ferrous metals, aluminum scrap, other nonferrous metals, glass cullet, inorganic fines, and mixed organics for fuel. These specifications represent first efforts to define uniform qualities of the materials recovered for sale and reuse and should add value to the outputs from resource recovery plants and promote user acceptance by providing a basis for quality assurance. These initial specifications will be tested and refined by NCRR in actual practice.

CPU–400

A major resource recovery process, developed under contract by the Combustion Power Company in Menlo Park, California, is the CPU–400. The process involves the high-pressure combustion of municipal solid waste and the direct conversion of the energy contained in the hot gas effluent to electricity by use of a gas turbine. Following successful low-pressure operation of the 100-ton-per-day pilot plant, the turbine was integrated into the system. Initial tests on the fully integrated system indicated its ability to burn solid waste efficiently and to generate full power output (100 kw) under complete automatic control. Subsequent tests, however, demonstrated that extensive deposits of alumina and silica develop on the first stage turbine stator blades after operating only for a few hours. Since the inefficiency of the inertial separators to remove extremely fine particulate matter from the turbine inlet gas was found to be the cause of the deposition problem, a more efficient particulate removal stage known as a "granular filter" is being developed. Subpilot research and development show promise of removing 97% to 98% of the turbine-bound particulate matter.

The EPA CPU–400 pilot plant was used for work sponsored by other organizations to test industrial wood waste and high-sulfur coal as fuel. The wood waste tests, sponsored by the Weyerhaeuser Company, featured a 100-hr demonstration run. In this run, deposits also formed on the turbine; however, this time it was kept in check by the periodic injection of walnut shells. The shells served as an effective on-the-run turbine cleaner, but a post-run inspection revealed some turbine blade erosion resulted from this cleaning operation. The experimentation using high-sulfur coal is being sponsored by the Department of the Interior's Office of Coal Research. Although some blade erosion resulted after some 50 hr of run-time on coal, the early efficiency to remove sulfur dioxide from the flue gas by using limestone in the fluid bed combustor was encouraging.

Incineration

The possibility of using processed solid waste to supplement various fossil fuels in industrial boilers with a capacity of up to 250 million BTU/hr is the subject of a research contract with the Thermo Electron Corporation of Waltham, Massachusetts. This study examines the technical and economic feasibility of refuse firing to produce steam for industrial processes or heating. Boilers already equipped for solid fuels are most readily adapted. Depending on fuel prices, refuse availability, etc., it may also be feasible to add a solids burning device and residue handling system ahead of existing gas or oil-fired equipment. The final report will define which boilers may be economically fired with refuse, the conversion equipment needed, and identify specific installations for possible further study.

Determining the overall environmental effects of various solid waste management practices is the subject of two SHWRL grants at the Columbus (Ohio) Research Laboratories of Battelle. The researchers assembled for these studies have extensive backgrounds in incineration, air and water pollution, plastics technology, corrosion research, land disposal, and heat recovery systems. One project is testing the environmental effect of using processed solid waste as a fuel supplement to crushed coal in a steam-electric power plant (Figure 88). The questions addressed here are the hazardous materials and plastics (particularly PVC types) in the waste, high versus low coal sulfur content, metal corrosion rates, air and water emissions, and the resource recovery value of solid waste. The City of Columbus' new shredding facility and two online municipal power plant boilers have been made available to Battelle to accomplish this study.

The second study is an environmental assessment of the role of all types of plastics in waste management practices—incineration, landfill, recycling, storage, collection and transport—and even as litter. A report covering Phase I of this study presents the current environmental effects. Phase II of the study examines the potential effects of future plastics usage and management practices.

ECONOMIC STUDIES

Economic research focused mainly on the problems of hazardous wastes and alternative control techniques. Policy strategies or measures for control of hazardous wastes involve direct regulation (e.g., disposal permits, treatment standards, licenses) or indirect regulation influencing economic decisions

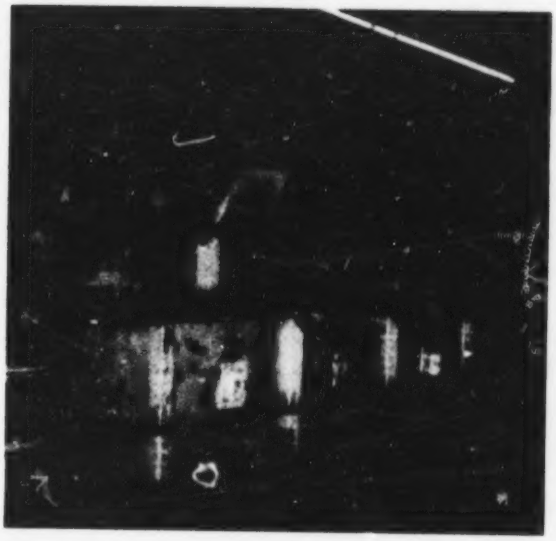

Figure 88. The 8-inch diameter flexible pipe (shown disconnected) is being used to pneumatically feed processed refuse to the boiler (replacing 40 to 50 percent of the coal fuel).

(e.g., taxes on emissions, recycling subsidies, disposal charges, and similar incentive devices to achieve social objectives). The administrative complexity and associated costs of a particular control program are important considerations of its efficiency and cost-effectiveness.

Controlling discharges of hazardous wastes to land involves a cost to society. On the basis of economic principles, the extent of control is suggested by comparisons between incremental reductions in damage costs and increases in control costs, with damage costs interpreted as society's "willingness-to-pay" for incremental levels of control of hazardous wastes.

Economic research continued on evaluating the efficiency of managing solid wastes. The applicability of materials-balance models was investigated. An EPA contract with Environmental Dynamics, Inc., developed taxation models for controlling the solid waste stream and considered substitution possibilities in production and consumptive uses. Economic incentives for encouraging increased supplies of recyclable materials were also examined. The final report suggested that taxation policies and subsidizing suppliers of recyclable materials can provide effective tools for managing solid waste.

The economic implications of various pricing mechanisms for solid waste management were also investigated. Traditional theoretical pricing concepts for allocating resources were applied, including the use of incremental user charges for collection and disposal of solid wastes. The study suggested that user charges can reduce household solid waste generation and reduce total system costs, although there is a tendency towards more self-disposal as prices for collection and disposal services are increased.

Research also continued on ways to increase the productivity of refuse collection crews. An experiment incorporating the use of a time incentive was implemented by a local municipality. The results will be monitored by the grantee during this next year.

A contract study of the effects of air and water pollution controls on solid waste generation was completed. Solid waste residuals were forecast to increase approximately four-fold by 1985 (over 1971 amounts) as a result of pollution controls. Solid residuals were identified for individual industrial sectors according to their original air and water pollutant constituents, and the treatment process applied. Major industrial sources of air pollution are power plants, steel production, cement and clay production, and nonferrous metallurgy. The largest contributors to water pollution are sewerage systems, paper products production, steel products production, and feedlot operations. Mining and agricultural wastes exceed all other industrial sources, but they were excluded from the analysis because these wastes are disposed of in the immediate area of generation and do not present any significant urban treatment and disposal problem.

Economic research in resource recovery was limited mainly to a study on the impact of subsidies in the paper industry. The research investigated the role of corporate organizational structures in decision-making processes related to capital investments and siting factors. It was observed that corporate management's concern for primary product production and preference for known quality and prices of inputs discourage the use of post consumer-type secondary fiber for paper production.

control of landfill leachate by biological treatment methods

The disposal of solid waste by sanitary landfilling and dumping is commonly practiced and occasionally results in the formation of leachate. The production of leachate (water that contains dissolved and suspended matter from solid waste) is caused by placement of solid waste in direct contact with surface or groundwater, or it occurs in a climate and soil environment where infiltration exceeds evapotranspiration losses at least during a portion of the year. Proper sanitary landfill design requires that significant quantities of leachate be controlled to avoid impairing the use of a surface or groundwater resource. Interception of leachate migration from a landfill requires treatment and, ultimately, disposal of this relatively small-volume (but initially highly contaminated) flow. At SHWRL, monitoring grants and contracts awarded to study control of this leachate is an important activity.

LEACHATE TREATMENT METHODS

Several investigators studied the treatment of sanitary landfill leachate, and promising results were obtained with a number of treatment methods. As will be shown, it was found that biological treatment methods are effective when treating leachate generated from a recent fill. Physical-chemical methods yielded better results than did biological methods when treating leachate generated from an old fill. An extensive study at the University of Illinois related the performance of each treatment method to the composition of the organic matter in the leachate.[1] In leachate from young landfills, about 70% to 80% of the organic matter consists of fatty acids. Because these organics are most easily removed by biological treatment, the use of extended aeration units, activated sludge units, and anaerobic filter units is appropriate in treating young leachate. After several years, the percentage of the fatty acid fraction decreases and an increase is observed in the substances with a molecular weight larger than 50,000. Since this fraction is best removed by physical-chemical methods such as coagulation and biological methods, a combination of the two will remove a satisfactory amount of the organic matter. The leachate from old fills has very stable characteristics and consists mainly of residual refractory material with a molecular weight predominantly between 500 and 10,000. Since this fraction shows good removal with activated carbon and reverse osmosis, these physical methods are to be employed when treating leachate from old fills.

AEROBIC TREATMENT OF LEACHATE

In an initial study, Boyle and Ham[2] showed that activated sludge is able to reduce the COD of undiluted leachate by 80% to 90%. Some foaming problems were encountered, however. The combined treatment of leachate and municipal sewage resulted in even higher percentages of reduction. Only when more than 5% of the influent volume consisted of leachate with a sludge age of less than 11 days, did the effluent COD experience a substantial increase and did the settling efficiency characteristics of the unit decrease. Lower volume percentages of leachate and higher sludge ages resulted in an effluent COD of 30 mg/l and a sludge volume index of 60.

The studies of Foree and Cook,[3] Cook and Foree,[4] Karr,[5] and Pohland and Kang[6] also evaluated the aerobic activated sludge treatment of leachate. The results are listed in Table 7. The data indicate a dependence between the substrate concentrations and the influent concentration.
High influent concentrations resulted in high effluent concentrations probably as a result of the higher concentration of resistant residual organic matter in the effluent. These high effluent COD values correspond with BOD values of less than 10 and confirm that most of the organic matter is present as stable refractory material.

In a German study that employed young leachate with a large amount of readily degradable organic matter, researchers found that a good effluent

TABLE 7. KINETIC CONSTANTS OBTAINED FROM BIOLOGICAL TREATMENT STUDIES OF SANITARY LANDFILL LEACHATE

Author	Treatment unit	Influent concentration, gm/l COD	Growth yield† Y (mg VSS*/mg COD)	Decay rate, b (day^{-1})	Max. growth rate, μ_{max} (day^{-1})	Substrate conc., K_S, mg/l COD
Foree and Reid (1972)[7]	anaerobic digester	12,900	0.33	0.17	1.39	633
Karr (1972)[5]	anaerobic digester	6,000	0.143	0.127	0.5	300
Pohland and Kang (1974)[6]†	activated sludge unit	270	0.50	0.014	0.66	41.3
Foree and Cook (1972)[3]	activated sludge unit	17,500	0.4	0.05	0.60	175
Karr (1972)[5]	activated sludge unit	1,550–4,500	0.29‡	0.10	1.0	1,460

*Volatile suspended solids.
†All values as BOD.
‡Determined from dehydrogenase activity.

quality could be realized with a 10-hr hydraulic detention time in the activated sludge unit. The effluent started to deteriorate, however, after a 6-hr detention period. The best removal was observed in a two-stage system, with hydraulic detention times of 6 and 16 hr, respectively.[8]

More heavy metals are generally removed in aerobic than in anaerobic systems. Although both anaerobic and aerobic treatment resulted in large reductions in the iron concentration in a Georgia Institute of Technology study[5] sponsored by NERC–Cincinnati, the reduction of calcium and magnesium was much larger in aerobic units. A similar result was obtained in the University of Illinois study,[1] where aerobic treatment was observed to reduce the iron concentration from 2,200 mg/l to less than 1 mg/l and the zinc concentration of 104 mg/l to less than 1 mg/l. Lower removal percentages were observed for calcium (99%), magnesium (89%), sodium (9.8%), and potassium (9%). A University of Kentucky study reported the removal of heavy metals from leachate obtained at the EPA Boone County Field Site were comparable (96% for iron; 97%, calcium; and 23%, magnesium).[3]

Schoenberger et al.[9] studied the need for adjusting the pH of the leachate to enhance the removal of the organic matter in activated sludge systems. No major effect resulting from pH adjustment by lime, sodium hydroxide, or sodium carbonate was noticed. Foree and Cook did find that nutrient addition, particularly phosphorous, and nutrient addition with pH adjustment improved the treatment performance slightly. These laboratory studies have not yet led to a large-scale application of leachate treatment; however, several recent sanitary landfill designs include provisions for leachate treatment.

Anaerobic Treatment of Leachate

Anaerobic treatment of leachate was first reported by Boyle and Ham who showed that with an influent COD concentration of 2,700 to 10,650 mg/l and a loading of 0.96 kg COD/m^3/day (0.06 lb COD/ft^3/day) a COD removal of more than 90% could be realized by anaerobic digestion. The effluent COD concentration varied between 225 to 4,125 mg/l. The authors recorded a negligible buildup of solids in the digester, which indicates a low yield factor. The study used a young leachate with large amounts of readily degraded organic matter. An aerobic polishing unit was able to reduce the COD of an anaerobic digester effluent from 740 to 445 mg/l, suggesting that a substantial portion of the COD was relatively nondegradable. More detailed anaerobic treatment studies were conducted by Karr, and Foree and Reid. They used completely mixed digester reactors in which the hydraulic detention time was identical to the solids retention time. Both studies also used a relatively young leachate; the results of these studies are also summarized in Table 8.

Although the effluent concentration of biological reactors utilizing simple sugars as substrate should be independent of the influent concentration, Karr found some dependence on the influent concentration, because the COD measures the total organic matter which includes the nondegradable substances in the leachate and in the activated sludge effluent. Such a dependence was not found for the BOD and total volatile fatty acids parameter, which indicates that these are better measures for the biodegradable organic matter. From the Karr, and Foree and Reid studies it can be shown that higher effluent concentrations are observed with higher influent COD concentrations. Similarly, a high influent concentration corresponded with a higher maximum growth rate and a higher subconcentration. The three reported studies[2,5,7] clearly showed that anaerobic digestion is an effective way to reduce the influent organic concentrations when a relatively young leachate is treated, since a large fraction of young leachate consists of free volatile fatty acids.

The anaerobic filter is a fixed bed reactor operated as an upflow clarifier in order to maintain saturation, and hence anaerobic conditions. When Foree and Reid compared the performance of an anaerobic filter to an anaerobic digester at identical volumetric loading, the COD of the unfiltered anaerobic filter effluent was 22% that of the COD of the digester effluent. Based on these promising results, a more detailed study using an anaerobic filter was conducted at the University of Illinois.[1] Preliminary results of this study (97% reduction of 30,000 mg/l influent COD) are similar to the results reported by Foree and Reid; no substantial further COD decrease was realized in both studies[1,7] using an aerobic activated sludge unit to polish the anaerobic effluent.

The anaerobic digestion, as reported by Boyle and Ham, resulted in the reduction of several cations and anions, with the largest reductions observed for manganese (98%), phosphorus (89%), aluminum (78%), iron (83%), calcium (70%), and zinc (31%). Karr found smaller metal reductions in most cases. All metal reductions were smaller than those observed for the aerobic systems.

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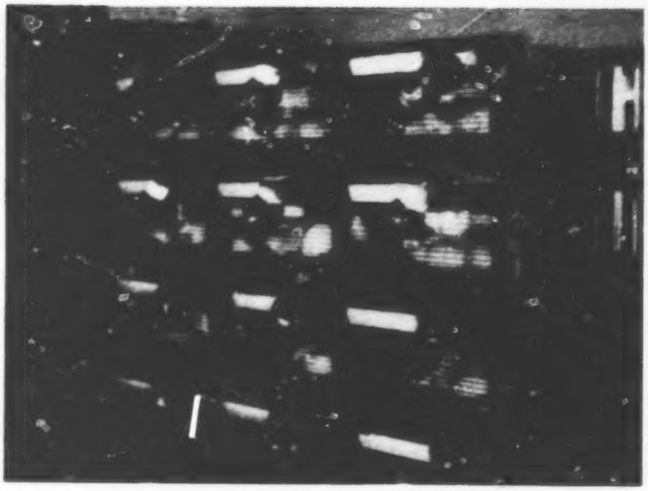

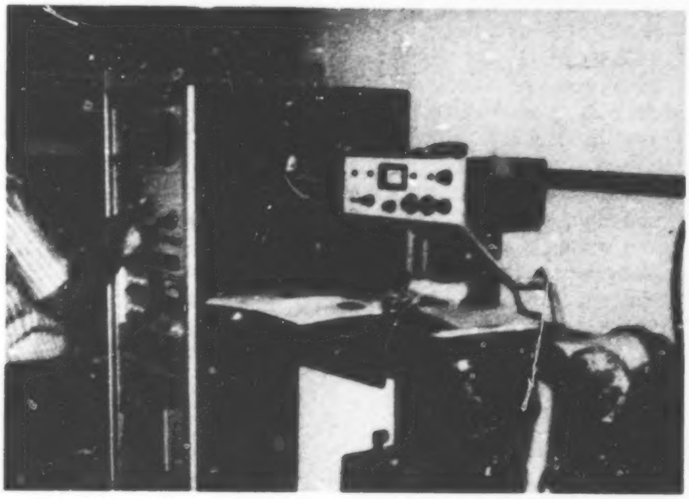

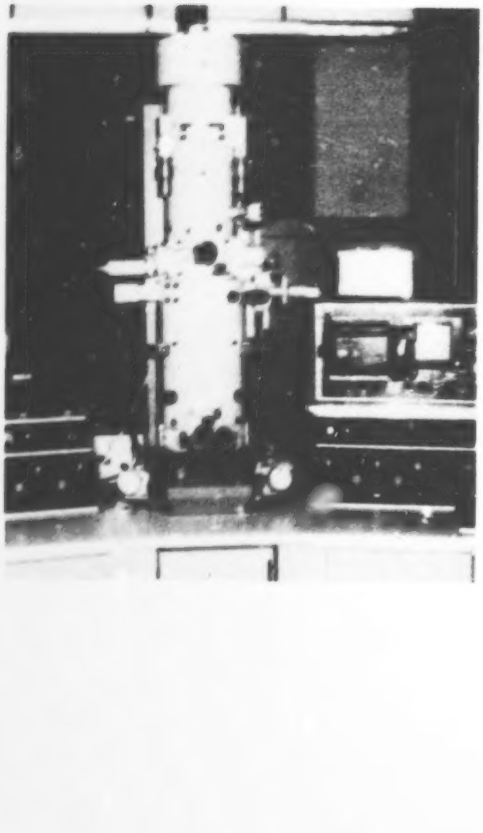

Figure 89. (top left) Pilot plant filters (sand, dual media, triple media, activated carbon).

Figure 90. (top right) Animal feeding studies to determine toxicity of drinking water contaminants.

Figure 91. (bottom left) JOEL 100B electron microscope used for asbestos fiber counting.

Figure 92. (bottom right) Finnegan GC/MS computer system.

water supply research laboratory

The Water Supply Research Laboratory (WSRL): develops the microbiological, chemical, and engineering technology necessary to ensure the attainment of drinking water standards and the maintenance of satisfactory drinking water quality throughout the distribution system; provides analytical and technical service to EPA regional offices and the Office of Water and Hazardous Materials; and performs health-effects studies necessary to develop criteria upon which to develop standards for drinking, recreational, and reuse waters.

STANDARDS ATTAINMENT STUDIES

Water Treatment

Inorganic Contaminant Removal

In 1974, laboratory tests for removal of cadmium were conducted. With contaminant levels in the range of 3 to 10 times the *Drinking Water Standards** limits, jar test results indicated lime softening could remove more than 95% of the cadmium. Coagulation with ferric sulfate at pH 8 gave about 80% removal.

Cincinnati tap water was used to operate the WSRL pilot plant at 8 to 10 l/min; sometimes bentonite (up to 13 turbidity units (T.U.)) was added. Bench-scale and pilot-plant coagulation tests, lasting up to 100 hr, confirmed the jar test results for mercuric chloride, selenate, and arsenate in the instances for which comparable bench-scale and pilot-plant testing had been done. Ferric sulfate was more effective than alum for removal of arsenate and mercuric chloride.

Particulate Removal

Studies on removing asbestos fibers from water were conducted with the use of a small, direct-filtration test system having a flow of 0.2 l/min and a filtration rate of 10 m/hr. Tests were made with granular dual media (coal-sand) and triple media (coal-sand-garnet) and with two different 19-m^3 (5,000 gal) shipments of Lake Superior water obtained from the Lakewood Pumping Station in Duluth, Minnesota.

Tests were conducted on an around-the-clock basis for the purpose of giving some guidance to the pilot-plant research being conducted on contract at Duluth. Important findings included the potential benefit of longer filter runs when the cold Lake Superior water was given some flocculation time between coagulation and filtration, as well as possible improvements in asbestos fiber removal by using a treatment combination of an anionic polymer, alum, and a cationic polymer. Certain chemical doses that were found effective in the small Cincinnati apparatus using in-line mixers generally proved to be too low in the granular media filters being studied at Duluth.

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*1962 U.S. Public Health Service Drinking Water Standards, Public Health Service Publication No. 956, U.S. Government Printing Office, Washington, D.C. 20402, 61 pp.

Organic Contaminant Removal

Capabilities in evaluating processes for the removal of organics from drinking water were expanded this year with the introduction of fluorescence spectroscopy and a rapid, yet sensitive, instrument for determining total organic carbon (TOC). As no single method measures the presence of all organics, these additions along with gas chromatography and the carbon chloroform extract (CCE) have been necessary in our adsorption and oxidation studies.

Oxidation. Three odorous compounds, styrene, 1,2-dichloroethane, and ethylbenzene, were tested for their removability with the use of ozone and potassium permanganate. Of these three, only styrene was removed well, but during ozonation the TOC concentration of the styrene test solution did not change. At very high doses of ozone, however, up to 75% of the TOC in Cincinnati tap water could be eliminated. A contract from the National Science Foundation for the verification testing of the Alron home ozonator was completed.

Adsorption. Field evaluation of an operating, granular, activated carbon bed continued at Davenport, Iowa, and another was begun at Little Falls, New Jersey. In the Little Falls test, three manufacturers' activated carbon are being tested in parallel. Effluent carbon chloroform extract by the miniaturized method (CCE-m), TOC, and fluorescence is being used to evaluate the performance of these beds. Also during the year, in cooperation with the Criteria Development Branch in WSRL, an evaluation of the carbon alcohol extract by the miniaturized method (CAE-m) portion of the organics-carbon adsorbable (O-CA) test led to the recommendation that this portion of the test be discontinued. Finally, the effectiveness of powdered activated carbon to remove other organic parameters such as CCE-m, TOC, and emission fluorescence scan (EmFS) was investigated. Up to 16 mg/l of powdered activated carbon had little effect on these parameters.

Halogenated Organics. Toward the end of the year, a major effort began on how to prevent the formation of halogenated organics during disinfection. The staff assigned to organic research was diverted from on-going studies to work on this important problem.

Microbiological Inactivation

Improved methods for preparing high-titer chlorine-demand-free virus stocks were developed. Stability of virus-clay complexes and the recoverability of these complexes by cell culture assay were investigated. Preliminary chlorine inactivation investigations of adsorbed virus and virus flocced with alum indicate that inactivation rates are similar to those of free virus.

Water Quality in Distribution Systems

Microbiological Quality

Many promising membrane filter (MF) media for the standard plate count procedure have been evaluated during the past year; the results from one are very encouraging. Results from 56 samples indicate that counts with this MF media are about 40% higher than corresponding counts using the standard pour plate procedure. The use of dyes in this medium as a colony counting aid still must be evaluated; but, the technique should soon be available for use in compliance with the new *Drinking Water Standards.*

Distribution line samples were collected weekly in cooperation with the Cincinnati Water Works during their scheduled flushings of dead-end mains. There were 135 samples collected from 32 different locations. Standard plate count (pour plate and MF) and spread plates were performed on all samples as well as MF tests for total and fecal coliforms, *Pseudomonas aeruginosa,* and fecal streptococci. The MPN multiple-tube test for coliforms was also performed. Bacterial densities ranged from 5/ml to 40,000/ml, with 44% of the samples having counts greater than 500/ml. Although bacterial densities were determined by both the standard pour plate and spread plate methods, the latter consistently produced higher counts. Coliform determinations using the MPN procedure resulted in seven positive coliform occurrences, as opposed to only one positive occurrence using the MF procedure. This variation indicates a possible desensitization of the MF method due to high bacterial populations or interference of pipe sediments on typical colony development.

The acquisition of a new liquid scintillation spectrometer for use in the rapid radiometric procedure permits automatic counting of radioactive samples and greatly increases experimental versatility. The problem of high background counts in experimental controls appears to be related to both the size and source of the carbon-14–labeled substrate. Promising results and increased test sensitivity were obtained with the use of selective media, and using uniform carbon-14–labeled compounds in the procedure may result in still greater sensitivity and will be investigated in future experiments.

Chemical Quality

Water Quality in Distribution Systems. The Mobile Water Quality Monitoring Laboratory built under contract by The National Sanitation Foundation has undergone a series of testing and evaluation studies.

A major effort has been directed toward controlling the on-board sensors and acquiring data for all parameters being monitored by computer. The on-board computer system punches out results on paper tape for later computer processing and analyses through time-sharing teletype services. We anticipate that with the use of the Optimum Systems Incorporated computer system we will be able to extend the capabilities for plotting data.

During an evaluation study, the laboratory was operated 24 hr/day for several successive days. During one of these studies, data were taken and analyzed for presentation at the national AWWA meeting in Boston. Eighteen parameters were monitored for that study (Table 8).

Efforts are underway to add iron and nitrate to our present capabilities. After further evaluations, the mobile laboratory will be used in the field in other cities to study the effect of water treatment on distributed water quality.

Asbestos Fibers. To determine if asbestos fibers are eroding from asbestos-cement (A/C) pipe, a "pipe-loop" of A/C pipe has been constructed. Two loops, about 33 m (100 ft) each are used: one, 10 cm (4 in) in diameter, the other 15 cm (6 in). Water circulates continuously through these two systems and is prefiltered before each pass so that "particle-free" water enters the pipe each time. Water leaving the pipes will be sampled continuously for asbestos fibers as determined by electron photomicrographs, electron diffraction patterns, and x-ray fluorescence. In succeeding tests, waters of differing pH's and hardnesses will be studied.

Quality of Raw Stored Water

Members of the American Water Works Association "Quality Control in Reservoirs" Committee have received their bottom-mud samplers, and are initiating a study to compile bacteriological data pertaining to water quality and the impact of stratification on reservoirs.

Data obtained on the Cruises Creek Reservoir (Walton, Kentucky) indicate the influence of stormwater runoff on water quality. The fecal coliform density appears to increase 10-fold between dry and wet period. Stratification does occur with fecal coliform, and streptococcus densities are greater at mid-depths (4 m; 12 ft) and bottom (approximately 7-8 m; 20-25 ft) than at the surface during dry periods. Pathogenic organisms (*Salmonella* sp.)

TABLE 8. PARAMETERS MONITORED BY MOBILE WATER QUALITY MONITORING LABORATORY

Parameter	Measurement	Detection limit
	In Drinking Water Standards and Guidelines	
Nitrate	Ion selective electrode	0.6 mg/l
Chloride	Ion selective electrode	3 mg/l
Turbidity	Light scatter	0.04 FTU
Total fluoride	Ion selective electrode (decomplexing buffer added)	0.1 mg/l
Cadmium	Anodic stripping voltametry	.001–.002 mg/l
Lead	Anodic stripping voltametry	.001–.002 mg/l
Copper	Anodic stripping voltametry	.001–.002 mg/l
	Not In Drinking Water Standards and Guidelines	
Hardness	Ion selective electrode	0.1 mg/l as $CaCO_3$
pH	Glass electrode	—
Conductivity	AC cell	—
Dissolved oxygen	Membrane electrode	0.1 mg/l
Temperature	Thermistor	—
Total residual Cl_2	Galvanic cell	0.1 mg/l
Free residual Cl_2	Galvanic cell	0.1 mg/l
Scaling	O_2 diff. through $CaCO_3$ film	—
Free fluoride	Ion selective electrode	0.1 mg/l
Alkalinity	Potentiometric	10–20 mg/l
Corrosion	3 electrode electrochemical	?

have been isolated only from feeder streams—not from bottom sediment of the reservoir proper. Data are continuing to be compiled to determine the impact of stratification and stormwater runoff on water quality of the Cruises Creek Reservoir.

Technical Assistance

Thirty-three State bacteriological laboratories and five water chemistry laboratories were surveyed in 1974.

In the surveillance of Interstate Carrier Water Supplies (ICWS) the evaluation of State water supplies and Federal water supplies, and in special studies, the following number of samples were analyzed for:

	Trace metals	*Complete chemistries*	*Pesticides*	*CCE-m*	*Misc.*
ICWS	—	137	66	67	—
State	107	97	—	—	68*
Federal	420	163	—	—	664†
Special	332‡	—	—	—	—

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*Selenium only.

†Total and fecal coliforms.

‡Boston Lead Study.

An additional 25 samples were analyzed for bis chloro ethers by gas chromatography, and 20 samples, for asbestos by electron microscopy.

In the way of general technical assistance (i.e., answering letters, telephone calls, preparing reports, and working on the drinking water standards) 1,911 man-days were spent by 32 staff members.

A graphite furnace attachment for an atomic absorption spectrophotometer is being evaluated to determine whether it is a more sensitive procedure for determining volatile metals, such as lead, cadmium, chromium, arsenic, selenium, and mercury.

Gas chromatographic procedures for the determination of bis chloro ethers and vinyl chloride are being investigated and being used to analyze for ethers in natural water and to study the possible release of vinyl chloride from PVC pipe.

An electron microscopic procedure utilizing electron diffraction and energy dispersive x-ray fluorescence analysis for identification of asbestos is being investigated and used to determine the ambient level of asbestos in selected finished waters from around the United States and to study the possible release of asbestos from A/C pipe.

CRITERIA DEVELOPMENT STUDIES

Organic Contaminants

Organic compounds in drinking water, by virtue of their multiplicity, concentration, toxicity, and interaction, pose a potential threat to the health and well-being of citizens throughout the United States. The definition of any and all adverse health effects that can be expected from exposure to contaminated tap water is the subject of a viable research program aimed at establishing criteria for the "safe" exposure to these chemical agents. The integrated approach consists of chemical, toxicological, and epidemiological investigations. The rationale requires (1) that the organics be concentrated and tested in biological systems appropriate for extrapolation to man, (2) that the organics present be identified, and (3) that toxic responses in experimental animals be investigated in the human population to assess risk.

Chemical Concentration

During the past year, several concentration and extraction media and techniques were investigated, including reverse osmosis using both cellulose acetate and aromatic nylon membranes, nonionic polymeric adsorbents, osmosis, and porous polymer adsorbents. After extensive experimentation, the operating parameters for concentration that employ cellulose acetate and nylon membranes were established and applied to a monthly sampling program of one water supply serving as the pilot for a broader sampling program. Investigations of macroreticular resins as a concentration tool led to the conclusion that nonionic polymeric adsorbents were inefficient for concentrating mixtures of compounds. An osmotic aqueous concentrator (OAC), recently invented by Gulf-South Research Institute, was obtained to determine whether the final concentration step, presently being performed through lyophilization, could be improved. Preliminary results with the OAC were encouraging; however, more extensive testing will be required to establish the increased benefit of this instrument. Porous polymer adsorbents were successfully applied to the recovery of volatile organics from water. The adsorbents were used in an instrumentation system called a Volatile Organics Analyzer (VOA) which was developed by the scientists of the Methods Development and Quality Assurance Research Laboratory of NERC–Cincinnati. This device not only allows the capture of the more volatile organic components that had previously escaped concentration and detection, but also enables the relatively simple introduction of the sample into analytical equipment such as a gas chromatograph and a combination gas chromatograph — mass spectrometer (GC/MS).

Chemical Identification

The identification of specific organic compounds requires the use of sophisticated instrumentation. During 1974, the Finnigan 1015 GC/MS having electron impact and chemical ionization modes was obtained and placed into service at NERC–Cincinnati and has been used by WSRL to identify these organic compounds. The instrument's data handling system was coupled to the mass spectral libraries of The National Institutes of Health and Battelle-Columbus for complete referencing. Control studies were conducted to evaluate and optimize the instrument in order to obtain the best possible spectra at maximum sensitivity. A reference compound, decafluorotriphenylphosphine, was adopted for routine efficiency analysis. The quality of the spectral data was maximized by applying unique software referred to as "Integration as a function of signal strength" (IFSS). Analysis of reverse osmosis samples and VOA samples of Cincinnati tap water identified 2-furaldehyde, methylene chloride, acetone, chloroform, bromodichloromethane, and chlorodibromomethane. Mass spectral analysis was employed to qualitatively compare the composition of various carbon extracts from drinking water. Analysis of the samples produced 12,000 spectra. The reconstructed gas chromatograms from the CAE and MCS-CAE samples were compared in detail; the evidence is conclusive that the samples were dissimilar. The comparisons of the CCE with the MCS-CAE are incomplete.

Analysis of Acrylamide in Coagulant Aids

Studies were conducted to determine the accuracy, sensitivity, and specificity of the EPA gas chromatographic method for the measurement of acrylamide monomer in water treatment polyelectrolytes. Samples of commercial polyacrylamide coagulant aids were analyzed by the EPA gas chromatographic method and, concomitantly, by mass spectral analysis. The results indicate conclusively that the gas chromatographic method is accurate and sensitive but that some substances may interfere with the analysis. The impurities that interfere with the gas chromatographic analysis produce erroneously high values of the monomer. Several of the products tested exceeded the EPA maximum allowable concentration of 0.05% for acrylamide.

Toxicity Assays

Organic concentrates generated by reverse osmosis or carbon adsorption were subjected to toxicity tests in mice. The results indicated that the reverse-osmosis-derived mixtures were moderately toxic by the intraperitoneal route and were only slightly toxic by the oral route. Hydrophilic fraction from three concentrates were tested and found to have potential for cumulative toxicity. The carbon-derived concentrates (CCE and MCS-CAE) were also found to be moderately toxic but did not display any cumulative toxicity. Animals treated with either carbon adsorbate demonstrated deep stupor and slow shallow breathing but no loss of irritability.

Studies were initiated to elaborate the toxicity of bis(2-chloroethyl)ether and bis(2-chloroisopropyl) ether. The first stage of experimentation, acute toxicity, indicates that the compounds are very toxic by the oral route.

Inorganic Contaminants

Toxicological Studies

The central nervous system effects of lead have been under study for the past year. *In vitro,* lead was seen to affect the kinetics of NAD(P)H oxidation and reduction in rat cerebral cortex slices at a concentration of 67 μm. These changes were accompanied by changes in the respiration and aerobic glycolysis of the tissues. Similar alterations have been observed *in vivo* with as little as 12 mg lead/kg of weight administered over a 14-day period (average of 0.87 mg/kg each day). The ability of orally administered manganese to produce the Parkinson-like syndrome shown to result from excessive inhalation of the metal is presently under investigation. In this study, the desirability of the practice of complexing rather than removing excessive manganese in drinking water will also be evaluated.

An effort to define the bioavailability of inorganic compounds in drinking water was begun this year. A contract has been let to synthesize radioactively tagged asbestos fibers. Radioactively tagged fibers will be used for quantifying the gastrointestinal absorption and the ultimate distribution of fibers in the bodies of experimental animals. A research grant has been awarded for the purpose of quantifying the relative absorption of cadmium from drinking water and comparing that with cadmium naturally occurring in food or admixed with the diet. In addition, the effect of certain hard water constituents (suspected factors in preventing cardiovascular disease) on the absorption of cadmium will also be investigated. These two projects will be the first of a series of similar studies with other inorganic constituents of water.

Cadmium has been implicated as a positive causal agent of renal hypertension. Its ability to damage tissues, most notably the testicles, kidney, and liver, is well documented. Although tissue damage is generally believed to result from a compromise of function at the molecular or biochemical level, the extent to which this function has to be damaged at this level, before its effects are noted in a disturbance of organ function, is essentially unknown. Animal experiments are being conducted to investigate the possibility that cadmium may be a contributing factor in the genesis, if not the maintenance, of human hypertension. It is postulated that cadmium accumulation in, and subsequent damage to, the kidney results in an adverse effect on the metabolism, activity or regulatory mechanisms of the enzymes and hormones of the Renin-Angiotensin System. Positive correlations will provide information to assist in assessing the possible toxic effects of chronic exposure to low levels of cadmium before symptoms of clinical hypertension manifest themselves.

Epidemiological Studies

A joint effort of the Water Supply Research Laboratory, the National Heart and Lung Institute, the National Center for Health Statistics, and the Bureau of Census was initiated to study the relationships between trace elements in drinking water and cardiovascular disease. This study involves the selection and physical examination of approximately 4,200 persons in 35 geographically distributed areas over a 15-mo time period; the sample areas and sample persons have been selected by the U.S. Census Bureau to be representative of the U.S. population. Water samples are collected from the person's home and water sources in the area and analyzed for those metals that are potentially related to cardiovascular disease. The results of the laboratory analysis of the water and the measurements of cardiovascular parameters obtained during the physical examination will be correlated to determine if there are significant relationships.

The sample person's cardiovascular function and condition will be determined by measuring blood pressure (three times), EKG, cholesterol levels; by securing a completed medical history and a cardiovascular questionnaire; and by obtaining other parameters determined during the physical examination such as chest x-ray. Water samples are to be analyzed for the following at the specified sensitivities: Na, K, Ca (100 μg/l); Li, V, Mn, Fe, Cu, Zn, Mo, Ag, I (1 μg/l); Cr, Co, Ni, Cd, Pb (0.1 μg/l); Mg, As, Se (10 μg/l); and Si, F, NO_3, hardness, alkalinity, conductance, pH.

An extensive review of the applicability of analytical methodology, particularly multielemental techniques, to the determination of trace elements in drinking water indicated that proton-induced x-ray fluorescence and spark source mass spectrometry appear to have broader ranges of applicability and greater sensitivities at the present time. One or both of these techniques will be used to determine those elements requiring a sensitivity in the 1 μg/l range or less.

During the past year an epidemiologic study was conducted in the Boston area to determine the relationship between blood lead levels and the lead concentration in household tap water. Approximately 300 households in Brighton, Somerville, and Cambridge (Massachusetts) were sampled according to the type of service line used (lead or nonlead pipe). Blood samples were collected from approximately 600 individuals in various age groups; a questionnaire was completed regarding socioeconomic factors and other sources of lead exposure; and environmental samples were collected (tap water, household dust, paint). The data are currently being analyzed.

Screening for Mutagenic/Carcinogenic Effects

Because of the expense and time required for animal studies in this area, efforts have concentrated on rapid, sensitive screening techniques, using mammalian cells or bacterial indicators, that can be applied to the assay of various chemicals or water samples directly. Standardization of the BUdR-visible light technique for determining mutant mammalian cells in the CHO–K1 cell line is essentially complete. All control experiments were completed and application of the technique as a bioassay system was initiated this year. Inorganics to be screened for mutagenic activity will include arsenic, beryllium, cadmium, cobalt, nickel, selenium, barium, chromium, copper, lead, manganese, mercury, and zinc. All chemicals screened for forward mutation using the BUdR-visible light isolation technique will also be tested for their ability to induce reverse mutations at the proline marker. Thus, the assay system is useful for confirming the mutagenicity of chemicals by two independent methods. Several experiments were carried out with respect to reverse mutation at the proline marker. Although all results obtained so far must be considered strictly preliminary, some very interesting trends have been noted. Data obtained from experiments on cells not receiving treatment with chemicals show a low "spontaneous" mutation rate. Ethyl methanesulfonate (EMS), a mutagen known to be able to revert the proline lesion, was tested at two different concentrations and found to produce mutation rates significantly above the spontaneous rate. Arsenic (As_2O_3) has also been tested, and these data suggest a mutation frequency for arsenic at least equal to that obtained with EMS, and possibly higher. On the other hand, all experiments with selenium (SeO_2) have, so far, yielded no revertants.

The first year of the grant to evaluate bacterial and/or mammalian cell monitors for use in screening municipal water supplies and sources for the presence of carcinogens was spent primarily in defining the test systems and evaluating the test systems with known carcinogens. The indicator systems were also employed on a limited number of finished and raw water samples from the lower Mississippi River. Indicator systems under investigation include histidine-dependent strains of *Salmonella typhimurium*, mouse embryo cell R616U infected with the AKR mouse leukemia virus, the rat embryo cell S1193h, and the human diploid cell WI–38. Significant reversion rates were obtained from active carcinogens with histidine-dependent mutants alone but not with compounds requiring metabolic activation. When liver homogenates were used to activate such compounds, significant reversion rates were obtained. A finished water sample and a river water sample produced significant reversion rates in the absence of liver homogenates. Infected R616U cells were transformed by carbon tetrachloride at concentrations as low as 0.1 μg/ml. One finished water sample and two river water samples produced altered patterns of S1193h cell growth. Since a working bacterial indicator system was found, the primary goal in the coming year will be the development of an efficiently functioning detection system and establishment of a standard technique applicable to all samples. For the mammalian cell monitors, further work on refining methodologies and techniques are required to ensure that a working system of high sensitivity is utilized. After the appropriate systems and methodologies are well defined, a number of raw and finished water samples will be screened from the lower Mississippi River.

Occurrence

Additional data are required on the occurrence of inorganics not included in the *Drinking Water Standards*, and a survey of community water supply systems was planned during the past year. The 35 areas currently included in the cardiovascular study will be sampled since this will provide results based on a statistical sampling of the U.S. population.

The applicability of multielemental techniques, such as neutron activation x-ray fluorescence, emission, and spark source mass spectrometry was reviewed for the analysis of water samples for inorganic constituents not in the *Drinking Water Standards*. Spark source mass spectrometry was selected since this technique appears to have a broader range of elemental applicability and greater sensitivity at the present time; it will be used to determine the occurrence of the following elements in the μg/l sensitivity range: B, Be, Al, Sc, Ti, Ga, Ge, Br, Rb, Sr, Y, Pd, In, Sn, Sb, Te, Cs, Ba, La, W, Pt, Tl, and Bi.

Microbiological Contaminants of Water Supplies

Virus Survey of Drinking Water

From six communities in Ohio, Indiana, and Missouri, 380-l (100-gal), finished water samples were collected and examined for viruses. The virus isolation-concentration method consisted of passing conditioned water through a stack of three 293-mm membrane filters of decreasing porosity, i.e., 8, 1.2, and 0.45 μm. This combination of filter porosities prevented the premature plugging of the concentration unit before the sample volume had been collected. Viruses adsorbed to the filters were eluted with 1 liter of pH 11.5 glycine buffer. The viruses were further concentrated by reducing the pH of the glycine eluate to pH 3.5 and then passing it through a stack of three 47-mm Cox filters. These smaller filters were then eluted with 10 ml of glycine elution media thereby giving a 37,850 concentration factor. The 10 ml were placed on monolayers of four cell types, and the cells were observed for morphological changes indicative of viral replication. This procedure has been tested in our laboratory and shown to consistently recover poliovirus 1 seeded at one virus unit per 380 l (100 gal) were examined.

A total of 41 samples were collected during the year. Five of these were samples in which a known virus was added at random to test the sensitivity of the method in the field. Each of these "positive controls" was a different virus serotype added at a concentration of 100 TCD_{50}/380 l (100 gal). Four of the five positive controls were recovered. Difficulty was experienced in collecting and eluting the sample containing the fifth positive control; this difficulty would explain the failure to recover the virus. Twenty-five of the thirty-six test samples have been completely processed thus far through the cell culture system. To this date, no viruses have been isolated from these samples.

Calibration of Virus Recovery Techniques

The current research effort is oriented toward evaluating several virus adsorbent systems for detecting low levels of virus in 380 to 1,900 l (100 to 500 gal) of water. The long range objective is to determine the minimum sample size required to consistently detect one virus in 380 l (100 gal) of water. To sample and condition such large quantities of water for viral adsorption enhancement, an apparatus was developed, constructed, and tested that effectively conditions unlimited quantities of water for enteric virus detection. Four candidate virus adsorbent systems for concentrating and detecting virus in 380 to 1,900 l (100 to 500 gal) of finished drinking water have been evaluated. The virus adsorbent systems were tested under simultaneous experimental conditions. The four virus adsorbent systems consisted of: Millipore membrane filters; AA Cox M–780 fiber glass microfilters; Balston fiber glass microfilter; and K–27 fiber glass depth filter coupled with an AA Cox M–780 fiber glass microfilter. A total of one hundred and fifty-six 100-gal (380 l) sampling runs and fifteen 500-gal (1,900 l) sampling runs were completed in the first 6 mo of this year. The model virus used in the evaluation test runs was poliovirus type 1 (vaccine strain). Virus inputs ranged from one virus (one infectious unit)/3.8 l (1 gal) to one virus/95 l (25 gal) in the 380 l (100 gal) sampling runs and one virus/ 76 l (20 gal) to one virus/209 l (55 gal) in the 1,900 l (500 gal) sampling runs. Analytical examination of the virus recovery data indicated no statistically significant difference in virus recovery efficiency among the four virus adsorbents tested. With few exceptions, virus was detected under all conditions of experimentation, which indicates that the method used to isolate virus, regardless of viral adsorbent selected, is highly sensitive. The success of the experimentation, coupled with the need for methods standardization for virus detection in water, resulted in the preparation and submittal of a tentative standard method for detecting virus in drinking water for the 14th edition of *Standard Methods for the Examination of Water and Wastewater*. The concomitant development of an apparatus for conditioning unlimited quantities of water and the demonstration of sensitivity of the method for detecting two to three virus units in 380 l (100 gal) of finished drinking water satisfies not only the logistics but also closely approaches the scientific requirements for effectively examining drinking water for enteric viruses.

Waterborne Disease Outbreaks

The outbreaks reported in 1973 were reviewed in 1974 and by polling the states, eight additional outbreaks were uncovered. Information, thus far, regarding waterborne outbreaks in the United States during 1973 shows:

- 24 outbreaks in 12 states, with a total of 1,720 cases,
- 16 of these outbreaks occurred in semipublic systems, 5 in municipal systems, and 3 in individual systems, and
- also, 690 cases of illness in outbreaks from water aboard cruise ships in the Caribbean.

Safe Recreational Water Quality Criteria

After finding the epidemiological and microbiological methodology pretested at the New York City beaches during the summer of 1973 to be not only satisfactory but also significant in understanding the difference in the illness rates of test and control beaches, the first year's study was conducted in the summer of 1974. In total, data were obtained on 14,000 persons at the beaches. For the persons who could provide a phone number so they could be contacted during the following week, a satisfactory set of illness data was obtained, and the data are being analyzed. The mail contact for persons without phones was not fruitful. The study will be repeated next summer to cover a range of beach conditions, and the interim criteria will be produced, as scheduled, in 1976.

Field Evaluation of Fecal Streptococcus Methods

Because available methods recommended to us for enumeration by membrane filter procedures of fecal streptococci were unsuitable when evaluated with samples collected locally and at the New York City beaches, we developed and satisfactorily evaluated a method for enumerating Group D streptococci (mSD).

Methodology for the Enumeration of Salmonella

A spin-off from the high-volume sampling procedure developed for enumerating *Salmonella* (HVS-S) in marine water was its successful application to potable water. The HVS-S, used in conjunction with the most probable number technique, allows enumerating salmonellae in up to 55.5 l of marine waters. The basic procedure (HVS) is now being used to enumerate total and fecal coliforms, in up to 380 l (100 gal) of potable water, in the study of the microbiological contaminants of drinking water.

Development of Methods for the Enumeration of Coliform Biotypes

An enumerative, membrane filter method for total coliforms and component genera, *Escherichia, Klebsiella*, and *Enterobacter-Citrobacter*, was developed and evaluated with samples collected from the New York City beaches during the summer of 1973 and 1974. By using a series of *in situ* tests superimposed on an initial selective differential membrane filter medium, we are able to recover data without recourse to picking colonies for identification.

Adapting Staphylococcus aureus Techniques for Use in Marine Waters

Existing membrane procedures for enumerating *Staphylococcus aureus* were found to be unsatisfactory for use in polluted marine waters. After an unanticipated delay, excellent progress is now being made on the development of the method, and an early completion date (January 1975) is anticipated.

Enumerative Method for Vibrio parahemolyticus

The method developed (mPA) involves a selective-differential primary membrane filter medium, an *in situ* test that screens out most organisms other than *Vibrio parahemolyticus*, and a single tube confirmation procedure. In a preliminary evaluation, it has been found satisfactory for the examination of water samples from the New York City beaches. This procedure should also prove of value as a means of detecting this organism and, with some modifications, other members of the genus *Vibrio* responsible for fish kills.

asbestos in drinking water current studies

Asbestos fibers are known to be a respiratory carcinogenic hazard. The question of whether ingested asbestos fibers are also a hazard has been raised and NERC–Cincinnati has been involved with studies directed at providing some short term answers. During the past year the Water Supply Research Laboratory conducted further activities designed to resolve questions related to analyzing and treating asbestos fibers in drinking water. A study was also initiated to determine if release of asbestos fibers from asbestos-cement pipe is a problem. An Environmental Protection Agency — Food and Drug Administration interagency chronic ingestion study of the carcinogenicity of ingested asbestos has been designed and will be implemented to answer some of the health effects questions that now exist.

Our analytical activities were a follow-up of problems experienced previously. As reported last year, initially over 50 Duluth area samples and over 200 treatment samples were analyzed by an optical microscopy procedure similar to that used by National Institute for Occupational Safety and Health for determination of airborne asbestos in a factory environment. Unfortunately, as subsequently established, optical microscopy is useless for detecting asbestos in most water supplies because the size of the fibers (less than 0.1 μm in diameter) usually found are too small to be visible. In January 1974, the Center's electron microscope became operational and an effort was made to develop a technique for using it to analyze for asbestos in water. It has been found that the instrument can be used for counting and sizing the fibers, provided electron diffraction and/or energy dispersive x-ray fluorescence is used to identify the fibers. Electron diffraction will classify the fibers as being either chrysotile, amphibole, or non-asbestos and if an energy dispersive x-ray fluorescence attachment is also available it may be possible to determine the kind of amphibole present. Because some waters contain a significant amount of other debris it may be necessary to first ash the filtered sample in a low-temperature oven to destroy the organic matter before undertaking analysis. Sampling also may be a problem since the asbestos particles appear to become attached to the other debris in the sample and to the container walls if stored for long periods before analysis. Care must also be exercised to be sure that samples are not contaminated in preparation for analysis as asbestos seems to be ubiquitous.

Although the method of analysis is still under development and perfection, about 20 treatment samples and 25 interstate carrier samples have been analyzed. Only about four of the interstate carrier samples were found to contain significant numbers of fibers.

After asbestos fibers were discovered in the drinking water of Duluth, Minnesota, and other nearby Lake Superior communities, a program of pilot plant research and water resources investigations was undertaken by EPA Region V and the St. Paul District of the U.S. Army Corps of Engineers. Technical assistance for the pilot plant research was provided by the Water Supply Research Laboratory in Cincinnati. The goal of the research was to evaluate diatomaceous earth filtration and granular media filtration for efficacy of fiber removal and clarification.

The pilot plant operation carried out by the contractor, Black and Veatch at Duluth's Lakewood Pumping Station, covered a time span from April through September. In 22 weeks of filtration studies, over 400 separate filtration tests were performed. The kinds of filters tested were: dual media, mixed media, pressure diatomite, and vacuum diatomite.

For the granular (dual or mixed) media filters, chemical combinations of inorganic salts (alum or ferric chloride) and polymers (nonionic, anionic, or cationic) were tested. Flash mixing with propellor mixers and in-line mixers was investigated. Filtration was tested with and without tube settlers in place.

Diatomaceous earth (DE) filtration investigations involved variations of DE size and treatment of DE.

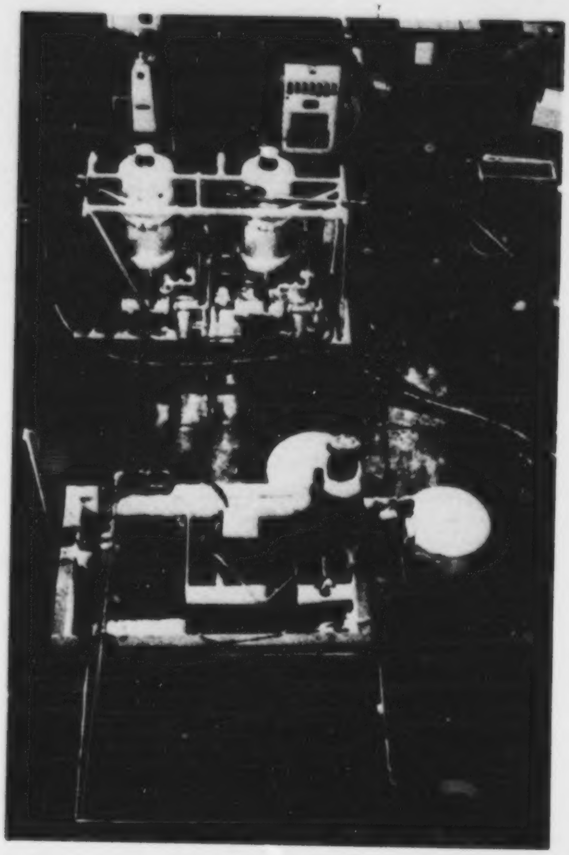


Figure 93. Pilot plant being used to evaluate filtration media for fiber removal (Duluth, Minnesota).

Diatomite for precoat and body feed was used without treatment as well as with alum coating or anionic or cationic polymer coating.

Analysis of the experimental data reveals that the most effective granular filtration method, as measured by effluent turbidity, involved use of alum and a nonionic polymer. At 4 gpm/sf with dual media, effluent turbidities averaged 0.20 T.U. vs. 0.10 to 0.15 T.U. for mixed media. Turbidities were lower (0.10 vs. 0.15) for mixed media with polymer addition in the flocculation chamber; and the use of two separate, sequential flash mixers for addition of alum and nonionic polymer lowered estimated chemical costs by about 10% as compared to less efficient mixing.

The Erdlator, a pressure diatomite filter, generally produced lowest effluent turbidities (0.12 or lower) when precoated first with a larger size of DE and then with a finer DE. The lowest chemical costs and lowest turbidities (0.06 T.U.) were achieved with a two-step precoat with alum coated diatomite in the fine precoat and alum coated body feed.

Analysis of EM data reveals that amphibole fibers were more easily removed than chrysotile. The use of alum and a nonionic polymer in a dual media filter operated at 4 gpm/sf resulted in removal of amphibole fibers to below detectable limits (BDL) in 9 of 10 direct filtration runs and 8 of 9 runs with tube settlers in place. In the mixed media filtration experiments, amphibole fiber removal to BDL occurred in three of four tests with alum and nonionic polymer added in two-stage flash mixing, and in two of two tests involving in-line mixers and sequential addition of alum and nonionic polymer as well as two of two tests with in-line mixers and sequential addition of anionic polymer, alum, and cationic polymer.

Amphibole removal by pressure diatomite filtration was most effective with a two-step precoat technique. Conditioning of both precoat and body feed diatomite with alum and soda ash gave amphibole removals to BDL in three of three runs.

Chrysotile removal proved to be more difficult. Removal to BDL occurred in one of four mixed media runs with two-stage flash mix for sequential addition of alum and nonionic polymer. With in-line mixers, one of two mixed media runs involving sequential addition of anionic polymer, alum, and cationic polymer gave removal of chrysotile to BDL. In the pressure diatomite filter, two-stage precoat and cationic polymer conditioning of the body feed gave a BDL chrysotile value on one of three runs.

The pilot plant research at Duluth demonstrated that asbestiform fibers could be removed by water filtration. However, proper chemical conditioning of the particulate matter in the water and/or the filter media is essential if fiber removal is to be achieved. Careful, diligent operation of the filter systems is also necessary. Under these conditions, filtration of public water supplies for asbestiform fiber removal ought to be successful.

The objectives of the study by WSRL with asbestos-cement pipe are to determine the influence of water velocity, aggressiveness of water, and elapsed times on the release of fibers from asbestos-cement pipe. To resolve these objectives a controlled pipe loop test of approximately 90 ft of each 4-in and 6-in asbestos-cement pipe will be subjected to continuous recirculation and sampling of water. Prior to entering the pipe systems the water will be filtered through 1.0 μm and 0.45 μm filters. The sample filters will be 0.45 μm so any fibers collected on them would be expected to come from the pipe. The flow rate through each pipe loop will be about 150 gpm. The principal water quality parameters will range from pH 5.5 to pH 9.5 and hardness of 20 to 400 mg/l.

Most of the equipment for the study has been obtained as of October 9, 1974, and will be in operation during the latter part of calendar year 1974.

The design of a study to elucidate the carcinogenicity of ingested asbestos was the central question of a committee composed of biological scientists from the Environmental Protection Agency, the Food and Drug Administration's Bureau of Foods and Bureau of Drugs, the National Cancer Institute, the National Institute of Occupational Safety and Health, and the National Institute of Environmental Health Sciences. The committee developed a chronic ingestion study using an experimental animal model used successfully in such types of previous investigations. According to the protocol, groups of animals will be exposed to graded doses (added to either food or water) of one of four types of asbestos: chrysotile, crocidolite, tremolite, or amosite. Utilizing the serial sacrifice approach, the study is expected to yield not only information on tumor incidence but also semi-quantitative data on the time of tumor appearance. This proposed study, which is scheduled for joint funding by EPA and FDA, has been recommended to the Director of NIEHS for final approval and is now awaiting funding.

During the past year, a research grant at the University of Rhode Island showed asbestos to be readily taken up by cultured mammalian cells. A study of the effects of asbestos in various types of mammalian cells, particularly ultrastructural changes, is in progress.

A contract has also been let to synthesize radioactively-tagged asbestos fibers which will be suitable for quantifying the gastrointestinal absorption and the ultimate distribution of fibers in the bodies of experimental animals.

throughout the world–international cooperation

AT HOME

Foreign Visitors

During 1974, NERC–Cincinnati received 213 foreign visitors representing national and local governments, industry, and academic or other institutions from 28 countries. Foreign visitors are very interested in our major water programs, the Advanced Waste Treatment Research Laboratory and the Water Supply Research Laboratory, and in our solid waste activities. The Environmental Toxicology Research Laboratory and the Industrial Waste Treatment Research Laboratory at Edison, New Jersey, also received a goodly share of visitors. The countries represented by these visitors (and their numbers) in 1974 were: Japan, 82; USSR, 27; Poland, 19; Germany, 14; Brazil, 10; Australia, 7; Denmark, 5; South Africa, Romania, the Netherlands, Italy, and Israel, 4 each; Dominican Republic, England, India, Sweden, and Switzerland, 3 each; Canada, Hungary, and Norway, 2 each; and Belgium, Czechoslovakia, China, France, Greece, Iran, Lebanon, and Thailand, 1 each.

Typical visits made to NERC–Cincinnati installations can be illustrated by those to the unique facility at Leonardo, New Jersey—the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT). A delegation of six Soviet maritime scientists visited the OHMSETT facility and Industrial Waste Treatment Research Laboratory (IWTRL) under the auspices of the U.S./USSR Agreement on Cooperation in the Field of Environmental Protection (working group on marine pollution from shipping) to follow through with technical discussions developed by the group during a meeting held earlier in the year in the Soviet Union. J. Stephen Dorrler of IWTRL and Alexander Seminov of the USSR were named co-project leaders on a proposed joint project to develop standard test procedures to evaluate the effectiveness of oil dispersing and surface collecting agents. Later, a French scientist, Mr. Mourlon, and a Canadian scientist, Mr. Ross, visited IWTRL to discuss oil-spill control technology and to explore future use of the OHMSETT facility in the Canadian oil spill program. As the result of a visit of delegates from the Bridgestone Tire Co., Ltd. of Tokyo, Japan, to the IWTRL and its OHMSETT facility to discuss the testing of an oil spill containment device manufactured by the company, a tentative testing schedule for Spring 1975 has been set.

Foreign Scientists Conducting Research and Receiving Training

Although NERC–Cincinnati has no formal research training program for visiting scientists, several requests are made each year by foreign governments and scientists to come here for work experience in special fields. During 1974, the following scientists, supported by the World Health Organization, conducted research and obtained training at the Water Supply Research Laboratory (WSRL), the Methods Development and Quality Assurance Research Laboratory (MDQARL), and the Advanced Waste Treatment Research Laboratory (AWTRL):

Name	*Position*	*Laboratory*	*Date*
Dr. Maria T. Martins	Chief Biologist, Public Works, Technical Center for Basic Sanitation, Sao Paulo, Brazil	WSRL and MDQARL	1/7/74 to 4/5/74
Dr. Mihaly Csanady	Head, Water, Chemistry Laboratory, State Institute of Public Health, Budapest, Hungary	MDQARL and WSRL	6/19/74 to 11/19/74
Luis A. Batiston	Supervisor, Virology Group, National Sanitation Works, Buenos Aires, Argentina	MDQARL and WSRL	6/3/74 to 7/19/74
Dr. Vladimir Zahradka	Senior Scientist, Water Research Institute, Prague, Czechoslovakia	AWTRL	10/16/74 to 2/75

While at NERC–Cincinnati, Dr. Martins worked with NERC research groups to learn about the techniques for detection and measurement of viruses in water. Dr. Martins will set up a laboratory for virus research in Brazil. In a previous year, NERC personnel visited Brazil to assist with this project.

Dr. Csanady received information and training in a variety of chemical analytical methods related to water. While working with the WSRL, he conducted useful research on the effects of water treatment processes on removal of cadmium.

Mr. Batiston worked with NERC personnel to learn the techniques for identification and recovery of viruses. This information will be put to use in his laboratory operations in Argentina.

Dr. Vladimir Zahradka is a visiting guest engineer with the Biological Treatment Section. Dr. Zahradka is investigating a unique process that combines the principles of chemical-physical and biological wastewater treatment. His work concerns the use of air stripping ammonia nitrogen from the main flow stream and coincident trapping of the existing air on a nitrification column. Dr. Zahradka's enthusiasm and engineering ability have contributed to rapid progress on the project.

ABROAD

Public Law 480 Projects

Under P. L. 480, United States counterpart funds in foreign countries are being used to finance projects designed to advance scientific and technical research in the particular country as well as in the United States. From NERC–Cincinnati, project officers supervise investigations relating to the identification and solution of environmental problems.

- *Physico-Chemical Treatment of Combined Industrial/Municipal Wastewater and Sludge Utilization*, Environmental Pollution Abatement Center, Katowice, Poland (Principal Investigator: Dr. Jan Suschka; EPA Project Officer: Dr. Herbert Skovroneck)

Initial attempts to optimize pollutant removal by coagulation of mixed wastewater high in dissolved and suspended iron have indicated that only partial treatment can be achieved, even with commercial coagulants. In June, the Project Officer and Dr. David Jenkins (University of California) visited Poland to obtain an update on the project and to make necessary changes to redirect the current campaign toward the development of a combined biological and physico-chemical treatment system acceptable for such a heavily loaded wastewater. The primary sludge, which is very high in iron salts, is being considered as a possible substitute for commercial coagulants. In October, Mrs. Kosarewicz and Mrs. Wysokinska, two of the principal scientists on the project, visited the United States to discuss the project and to tour various industrial facilities and waste treatment plants.

- *Solid Wastes in India*, National Environmental Engineering Research Institute, Nagpur, India (Principal Investigator: Mr. A. D. Bhide, Head, Solid Waste Division; EPA Project Officer: Mr. Louis W. Lefke)

The purpose of this study, started in 1971, was to examine current solid waste management practices in India and to determine the characteristics of municipal refuse. Such information will be valuable in future planning and in making immediate recommendations as to the methods of collection, transfer, and disposal that are best suited to conditions in India. This will also help identify areas where research and development efforts need to be concentrated.

A final report has been received and this study has resulted in several important conclusions. First, processing and disposal techniques commonly used in western countries are not directly applicable in India since Indian solid waste contains much higher percentage of earth and compostable fraction with much lower percentage of paper, plastics, and glass than normally found in the West. Second, efficient operation of any solid waste system requires proper delegation of responsibility to highly competent employees at all levels. Since many solid waste management functions are engineering oriented, suitably trained public health engineers should be entrusted with the job. Such a practice could substantially improve conditions in India. Third, the total cost of solid waste management could be reduced by using vehicles specially designed for the purpose, instead of the currently employed vehicles originally used for other activities. Money saved by cutting the cost of solid waste transport (the most costly part of solid waste management in India) could be invested in upgrading disposal practices. Fourth, Indian solid wastes are found to contain intestinal parasites *Ascaris lumbricoides* and *Trichuris trichiura.*

This survey has yielded much useful information on solid waste practices and on the composition of solid waste in India. It has also provided the basic information of vital importance in planning future research effort.

- *Neutralization and Utilization of Post-Coagulation Sludges*, Research Institute on Environmental Development, Warsaw, Poland (Principal Investigator: Dr. Pawel Blaszczyk; EPA Project Officer: Dr. Robert B. Dean)

This project deals with sludges produced by water purification with alum. The sludges produced when dirty river waters are coagulated resemble sludges produced by similar coagulation of wastewaters. Two major objectives being studied are reduction of volume of the aluminum hydroxide sludges and recovery of alum. A third objective is to evaluate the impact of alum sludges on wastewater treatment plants.

- *Utilization of Sewage Sludge from Combined Treatment Plant*, Institute of Meteorology and Water Economy, Wroclaw, Poland (Principal Investigator: Dr. Josef Cebula; EPA Project Officer: Dr. Robert B. Dean)

This project deals with the sludges from mountainous areas where there are industries based on natural fibers and leather. All drainage to a water supply reservoir is to be collected, and the sludges will be combined for utilization in agriculture. In addition to evaluation of potential contaminating elements in the area sludges, a study will be made of the effects of metals in the Wroclaw sewage farm that has received urban waste waters and sludges for 90 years without adverse effects on the farm produce.

The principal investigator visited the United States twice in the current year, and the project officer, Dr. R. B. Dean, has visited Poland two times in the previous years to coordinate both Polish projects.

- *Development of Methods and Techniques for Final Treatment of Combined Municipal and Textile Wastewaters Including Sludge*, Water Economy Research Institute, Katowice, Poland (Principal Investigator: Dr. Jan Suschka; EPA Project Officer: Dr. Robert L. Bunch)

Various wastewater treatment processes are being evaluated as to their efficacy in treating a combination of domestic and textile wastewater. A list of typical dyes used in dyeing both natural and manmade fibers has been compiled. From this inventory of dyes, the most popular dye used from each class of dyes was chosen for determining adsorption isotherms with the use of activated carbon. There was a wide range in the adsorptive capacity of the carbon for the seven dyes tested: from 5,630 mg/g of carbon for the sulfur dyes to 20 mg/g for a dye in the reactive dye class.

Because the primary sludge tends to adsorb the dyes, the concentration of the dye in the sludge can be more than six times that of the raw sewage. Some of the dyes are toxic to digester operations. Many of the metal complex dyes prevent methane production when added at 1% of the sludge.

- *Factors Influencing Lead Absorption from the Intestine*, Institute for Medical Research and Occupational Health, Zagreb, Yugoslavia (Principal Investigator: Dr. K. Kostial; EPA Project Officer: Dr. Jerry F. Stara)

This project includes studies concerned with: the influence of lead on calcium and strontium transfer through the duodenal wall in rats; comparative transport of lead-203 and calcium-47 from mother to offspring during pregnancy and lactation; and lead acetate toxicity in rats in relation to age and sex.

- *Epidemiological Study of Methemoglobinemia in Croatia*, Institute of Public Health in Croatia, Zagreb, Yugoslavia (Principal Investigator: B. Plese; EPA Project Officer: Mr. Leland J. McCabe)

The project is an attempt to correlate the methemoglobin levels in infants with the nitrate ingested with drinking water. To date, the research team has examined several hundred children and found methemoglobin levels as high as 20% with 20 clinical cases of methemoglobinemia. The clinical cases provide an opportunity to study factors that allow some children to develop the disease and not others. Methemoglobin reductase activity in the study population does not seem to be a factor.

- *The Role of Silicates in the Etiopathogenesis of Endemic Nephropathy*, Belgrade University Medical School, Belgrade, Yugoslavia (Principal Investigator: A. Bata; EPA Project Officer: Mr. Leland J. McCabe)

Dr. Robert Tardiff of Water Supply Research Laboratory made a 3-day site visit to the project and developed plans for the next year's research. The project is an attempt to determine if endemic nephropathy (Balkan nephritis) is caused by silicates in the drinking water; the project will also provide some basic data on the health effects of silicates. To date, experimentation has consisted of two studies. In the first, groups of rats were given graded doses of ground quartz in their drinking water for 1 year. In the second, animals were maintained on water (taken from a well from the endemic area) containing a high concentration of silicate. The results of the first experiment indicated that some mild histopathological changes were observed in the kidneys of animals treated with quartz. All other results were negative.

NERC Visits Abroad

Dr. Peter B. Lederman, Director of the Industrial Waste Treatment Research Laboratory, visited river basin authorities in Germany, France, and the Netherlands to discuss various industrial waste problems, particularly industrial/municipal treatment.

Dr. Robert G. Tardiff visited Yugoslavia, Denmark, the Netherlands, and England to monitor a P.L. 480 Grant and to exchange information on the toxicity of environmental chemicals.

Mr. Edwin E. Geldreich participated in a Geneva Conference with a Group of Experts on Scientific Aspects of Marine Pollution to complete work on biological parameters in a marine pollution monitoring system.

Dr. James M. Symons visited France, the Netherlands, Switzerland, Germany, and the United Kingdom. He presented a paper at the 10th International Water Supply Congress in the United Kingdom and held extensive talks with water authorities in the other countries on mutual water treatment and analytical problems.

Dr. Shih L. Chang traveled to Belgium, Germany, Austria, and Switzerland. He presented a paper in Munich at the 3rd International Congress on Parasitology and visited institutions in the field of parasitology in the other countries.

Dr. Gerald Berg was chairman of the session on "Indicators of Sewage Pollution" at the International Symposium on Discharge of Sewage from Sea Outfalls held in London, England. *Dr. Elmer W. Akin* attended this meeting and presented a paper. With *Mr. Francis Middleton*, both Dr. Berg and Dr. Akin also attended the International Association on Water Pollution Research in Paris, France, where Dr. Berg presented a paper and Mr. Middleton chaired a session. Dr. Berg further attended the Conference on Viruses in Water in Mexico City and chaired the panel on Reclamation and Disposal.

Dr. Norman A. Clarke attended an invitational Conference on Viruses in Water in Mexico City where United States practices and EPA programs were discussed.

After a delegation of three Polish engineers visited the Mining Pollution Control Branch laboratory to discuss the effect of acid mine drainage on industrial wastewaters and treatment alternatives, *Mr. Ronald D. Hill* then visited Poland, where several projects concerning treatment methods for water pollution problems from coal mining were discussed.

At the request of the Bahamian Government, *Mr. John S. Farlow* visited this Caribbean country to obtain background information for a technical report recommending the establishment of an oil pollution management system. The recommendation includes a suggested legal structure for prevention and control of oil spills, identification of sources of potential spills, establishment of an inventory of cleanup and control equipment, and training in response to a request originating from the Pan American Union.

In the summer of 1974, *Dr. Jerry F. Stara's* travels in Europe included: a review visit on a Public Law 480 project to Zagreb, Yugoslavia; attendance and presentation of a paper at the International Symposium on Recent Advances in the Assessment of Health Effects of Environmental Pollution in Paris, France; a visit to the National Institute for Oncology (Professor Maltoni) in Bologna, Italy, to review the vinyl chloride carcinogenesis data; and attendance and presentation of two papers at the World Congress for Environmental Biology and Medicine, in Paris, France. In addition, the Environmental Toxicology Research Laboratory staff had a number of contacts concerning either review of documents or proposals for research projects with the following countries: Poland, Belgium, India, and Israel.

A number of internationally significant events took place that did not require foreign travel by NERC–Cincinnati personnel. Some of these events included: Solid and Hazardous Waste Research Laboratory (SHWRL) participation in the "Symposium on Control of Fine Particulate Emissions from Industrial Sources" (January 14-18, 1974, San Francisco), sponsored by the U.S.-USSR Working Group on Stationary Source Air Pollution Control Technology, after which SHWRL served as one of several hosts to the Soviet delegates on subsequent visits to inspect the CPU–400 project and a fabric filter installation on an oil-fired power plant. In April 1974, SHWRL also participated on the Particulate Committee of the Working Group that met in Washington to develop a detailed protocol for an information exchange and a joint research program to be carried out under the terms of a 1972 treaty for cooperative activities in environmental affairs. As a result of visits from solid waste experts from foreign countries, considerable rapport has developed between scientists in SHWRL and such countries as Israel, Japan, and Germany. A considerable technical exchange of information on current studies, available reports, and solutions to problems beneficial to both countries has developed.

The 10-min color videotape on "CAM-1" (see TV Production Unit section), prepared at the request of Mr. Fitzhugh Green, EPA Office of International Activities, was featured at the September 1974 meeting of the Society for Water Treatment and Examination at Reading, England.

INTERNATIONAL ORGANIZATIONS, WORKING AGREEMENTS, AND CONFERENCES

International Joint Commission — United States/Canada

Mr. Dwight G. Ballinger, Director of the Methods Development and Quality Assurance Research Laboratory, served as Chairman of the Standing Committee on Analytical Sampling and Measurement Methods, Research Advisory Board, International Joint Commission. At regular meetings of the Committee held in Canada and the United States, reports are made of research needs and on-going research in both countries.

Mr. Leland J. McCabe of the Water Supply Research Laboratory is a member of the Medical Committee of the Great Lakes Research Advisory Board whose function is to identify immediately and anticipate future health problems in the Great Lakes and to assess research needs.

Throughout the year, Mr. John J. Convery, Director of the Advanced Waste Treatment Research Laboratory, served as a member of the Standing Committee on Water and Wastewater Treatment, Research Advisory Board, International Joint Commission. At regular meetings of the Committee held in Canada and the United States, reports and recommendations on research needs and on-going research in both countries were discussed and recommendations forwarded to the Research Advisory Board. Reports relating to PCB's have been reviewed. The Committee is working on guidelines to good practice in the wastewater treatment field.

United States — German Cooperative Program in Water Pollution Abatement

This program was established in 1966 and has proceeded informally. Dr. Robert B. Dean, the designated representative for sludge, met with the German designate, Dr. Professor W. Niemitz, Institute for Water, Soil, and Air Hygiene of the Federal Health Office, during a visit to Berlin in May. He also visited the new Berlin sludge treatment plant that incorporates heat treatment of sludges.

United States — Japan Conference on Sewage Treatment Technology

One of the results of the United States/Japan Ministerial Conference on Environmental Pollution held in Washington, D.C., in June 1971 was the establishment of a Joint Sewage Treatment Technology Conference. Both the United States and Japan are engaged in a very large construction program of wastewater treatment plants. New water-quality demands require extensive research for bettering treatment technology. Three Joint Conferences, two in Japan, have been held between expert teams on both sides to exchange knowledge in the treatment area.

In February 1974, Mr. Francis M. Middleton, Deputy Director of NERC–Cincinnati headed a team (composed of Mr. Jesse M. Cohen, Mr. Edwin F. Barth, Dr. Joseph B. Farrell from NERC–Cincinnati and four others) that visited Japan to hold the Third Conference. As part of the agreement, Japanese engineers have come to Cincinnati for training and joint exchanges of information have been set up between the United States and Japan.

International Standards Organization (ISO)

Mr. Dwight G. Ballinger is the EPA representative to Technical Committee 147 of the ISO. As a member of the U.S. delegation, he is responsible for preparing analytical methods for possible adoption as international standards. While in Europe, Mr. Ballinger also established liaison with the International Organization for Legal Metrology, a group of government representatives responsible for international cooperation in establishing legal standards of measurement.

World Health Organization

In August 1973, the World Health Organization (WHO) requested Dr. Andrew W. Breidenbach, the NERC–Cincinnati Director, to serve as the leading consultant for a group of experts on a project aimed at abating and controlling environmental pollution in the Upper Silesia Region. For this project (designated UNDP/WHO Project Poland 3102), the World Health Organization is collaborating with the Government of Poland concerning the establishment of an environmental pollution abatement center in Katowice, Poland. Dr. Breidenbach, chosen because of his experience in planning and administering regional environmental protection programs, worked with a panel that included a specialist in air pollution control planning, water policy planning, and solid waste management. All worked closely with counterpart Polish scientists, and the consultant's reports were made final at an April 1974 meeting.

As a consultant to the European WHO, Mr. Dwight G. Ballinger served on the Working Group on Physical and Chemical Examination of Water at a meeting held in Prague, Czechoslovakia. The working group is responsible for the preparation of a manual of test procedures for use by the European community. Mr. Ballinger's participation helps to ensure consistency with American practice and EPA interests.

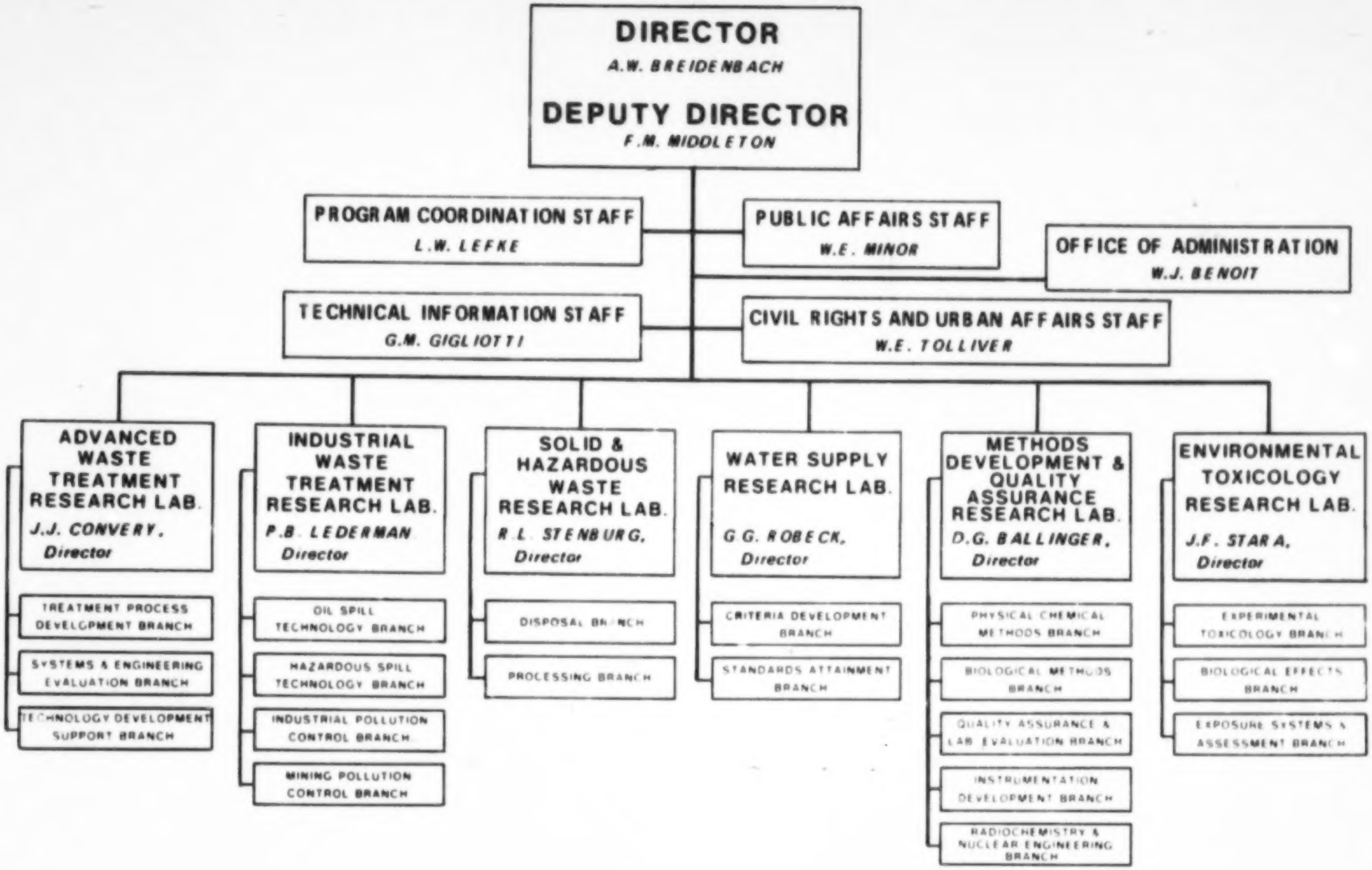
Committee on Challenges to Modern Society

This is a NATO-sponsored committee; the United Kingdom is the lead country on a project in advanced waste treatment.

Dr. Robert L. Bunch participated in the Workshop on Advanced Wastewater Treatment held in Canada, hosted by the Canadian Environmental Protection Service of the Environment. Participating countries at the meeting were Canada, Norway, Germany, Italy, England, and the United States. Scientists from the member countries discussed activities in their countries relating to nutrient removal, sludge handling and disposal, and physical-chemical wastewater treatment.

Organization for Economic Cooperation and Development (DECD)

Dr. Robert L. Bunch served as a member of the Expert Group on the Biodegradability of Nonionic Synthetic Detergents. The Expert Group expressed the opinion that the "screening test" described in the DECD publication on anionic surfactants may be used to give an indication of the biodegradability of nonionics. The Wickbold analytical procedure for the determination of the nonionic concentration is to be used in place of the methylene blue method for anionic surfactants. The "confirmatory test" described in the same DECD publication can be used but presents a number of deficiencies—in particular, the variabilities between results obtained in different laboratories and the effect of low temperature on the rate of biodegradation of nonionic surfactants.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